APRIL, 1961

Welding Journal

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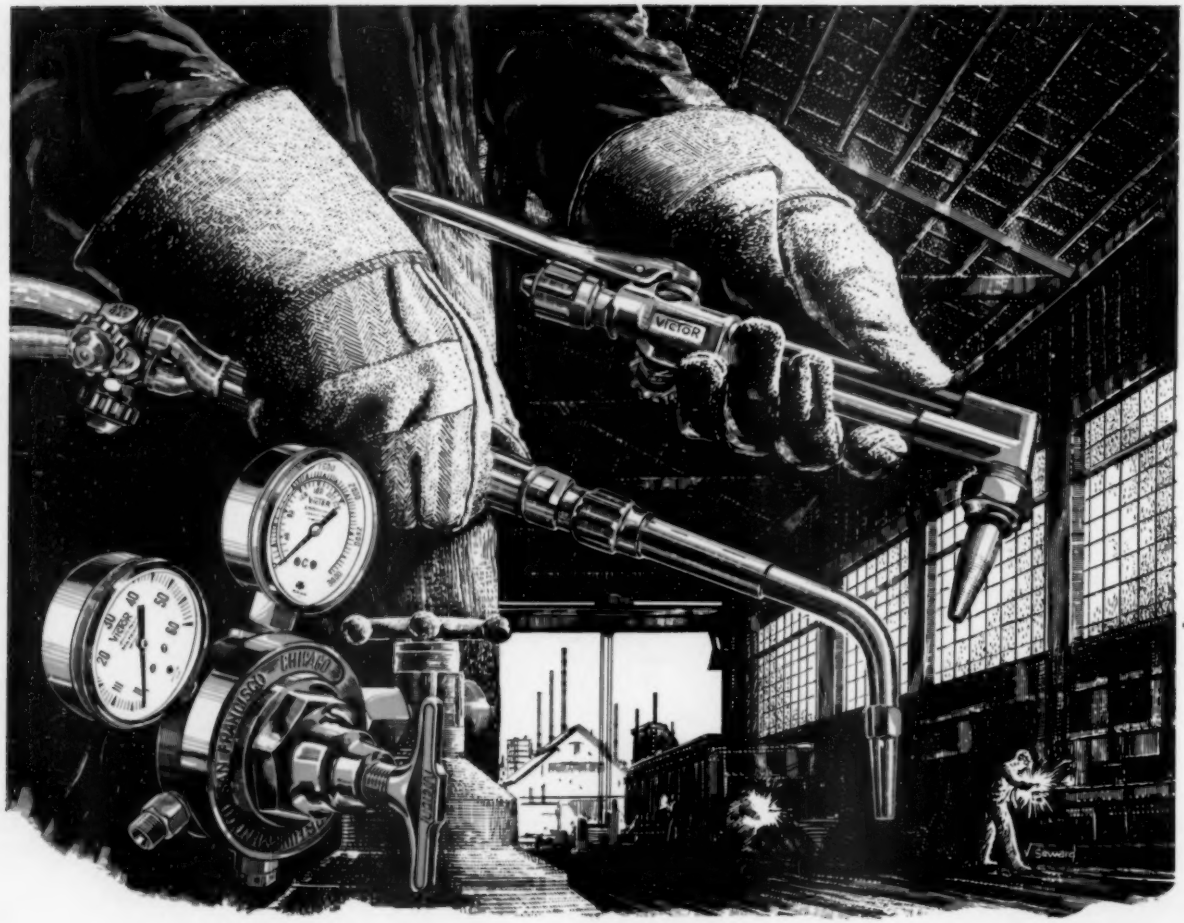
42ND ANNUAL MEETING AND EXPOSITION

OFFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY



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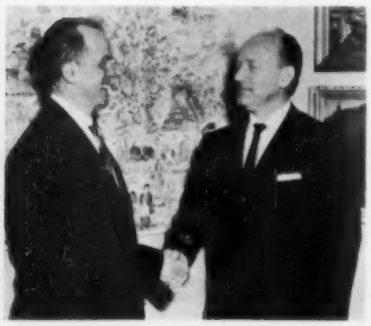
PRESS-TIME NEWS ...about ...People ...Welding ...Products

Eutectic Elects Chairman and New President

Leonard C. Barr AWS has been elected president of Eutectic Welding Alloys Corp., Flushing, N. Y., it was announced recently by Rene D. Wasserman AWS prior president and founder of the company. Wasserman, who founded Eutectic 21 years ago and has built it to $30 million in annual sales, was elected chairman of the board of directors.

Barr comes from Gregory Industries, Lorain, Ohio, where he was executive vice president. He was a founder of Gregory Industries and remains a director and one of its largest stockholders. Barr is also a director of the Wakefield Co., Vermillion, Ohio. He joined Owens-Corning Fiberglas Corp. following graduation from the University of Illinois in 1939. In 1943 he joined the Nelson Stud Welding Corp., San Leandro, Calif. In 1948 he joined with George E. Gregory in founding Gregory Industries, which acquired the Nelson Stud Welding firm.



L. C. Barr (left) and Rene D. Wasserman

Barr is a member of the American Management Association, the AMERICAN WELDING SOCIETY, the National Industrial Conference Board and the Cleveland Engineering Society. He is a member of the National Council of the Boy Scouts of America, and in 1960 received the Silver Antelope, the Scouts' highest award for service.

Mr. Wasserman has been president and director of research of Eutectic since its establishment in 1940. He is inventor or coinventor on more than 60 of the company's basic patents. Active in the Young President's Organization and the AMERICAN WELDING SOCIETY, he is especially concerned with the international arm of the YPO and is an AWS delegate to the International Institute of Welding.

Credit Due Committees

Combined efforts of members of the New York, New Jersey and Long Island AMERICAN WELDING SOCIETY sections are making this year's Annual Meeting and Exposition possible. The meeting promises to be the biggest in AWS history.

Under the chairmanship of J. E. Dato, assistant manager of welding, Linde Co., the Arrangements Committee is responsible for all meeting arrangements including the President's Reception and Banquet on April 17th.

Heading the President's Reception, Hospitality, Signs and Technical Committee is H. D. Landis, welding engineer, Armco International Corp. Chairman of the Technical Meeting Sessions Committee is J. Mikulak, assistant to the vice-president-in-charge of manufacturing, Worthington Corp. M. J. Giraldi, surveyor, American Bureau of Shipping is chairman of the Banquet Committee.

Co-chairmen of the Ladies' Entertainment Committee are H. C. Cook, assistant, Pipeline Research Div., Esso Research and Engineering Co., and J. W. Flannery, plant welding engineer, International Nickel Co. Plant tours are being coordinated by E. W. Moles, welding engineer, Grumman Aircraft Engineering Corp. and the Tours Committee. Publicity Chairman is A. V. Scherer, advertising manager, Air Reduction Sales Co.

SNT to Meet in Montreal

Montreal in Quebec, Canada, will be the site of the first Eastern Regional Convention of the Society for Nondestructive Testing, May 17–19.

The convention will consist of 24 papers presented at eight sessions by nondestructive testing authorities. An educational clinic will also be conducted on May 19th concerning topics such as radiography, ultrasonics, and magnetic-particle and dye-penetrant testing.

Activities will include a ladies' program consisting of a luncheon, sightseeing tours, and a shopping tour.

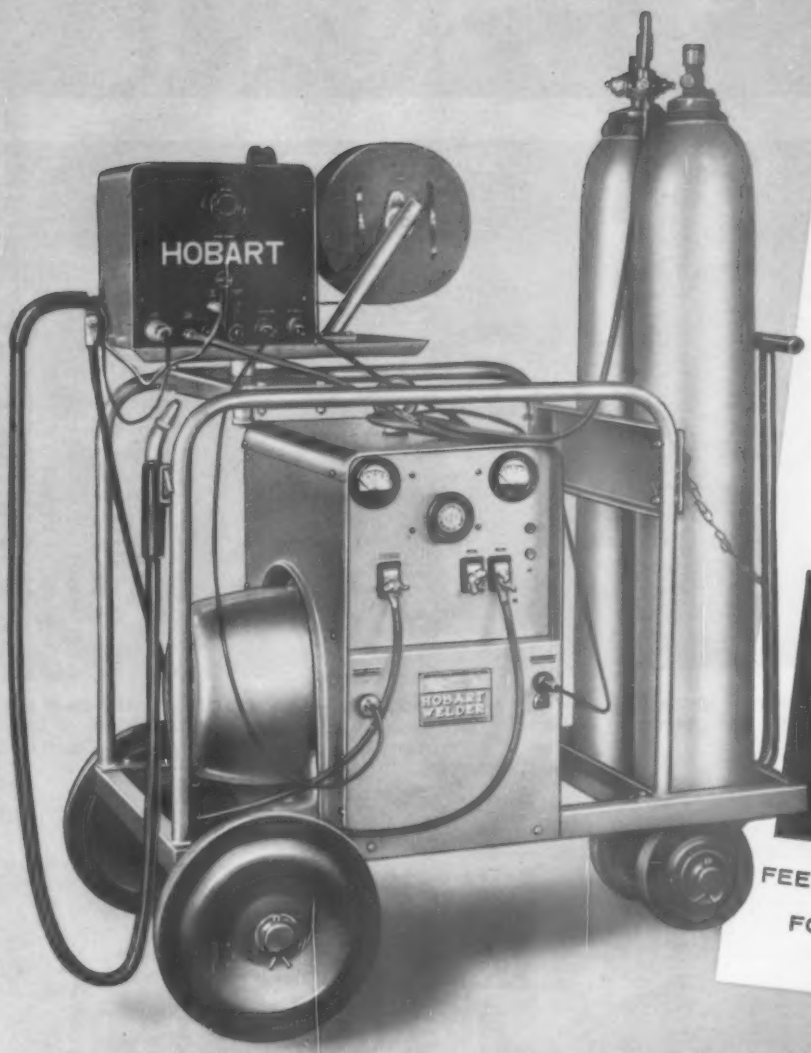
Inquiries can be directed to SNT at Montreal P. Q., P. O. Box 772, or to M. Daley, 2168 Addington St., Montreal 28, Quebec, Canada.

Weldmation Corporation Formed

Formation of a new company, Weldmation, Inc., was announced recently by Arthur F. Kelsey, president. The new corporation located at 1505 E. Eight Mile Rd. in Hazel Park, Mich., will design, and manufacture all types of automated resistance and arc-welding machinery for the sheet metal fabricating industry.

Detroit Industrialist Robert L. Deary will serve as vice president, with George J. Prowse AWS, who has been associated with Kelsey for several years in the welding industry, will be secretary and treasurer of the newly-formed corporation.

Both special and standard types of welding machines will be produced by Weldmation. They expect to employ approximately 100 people including designers and engineers. The new plant contains all completely modern and up-to-date manufacturing equipment and facilities.



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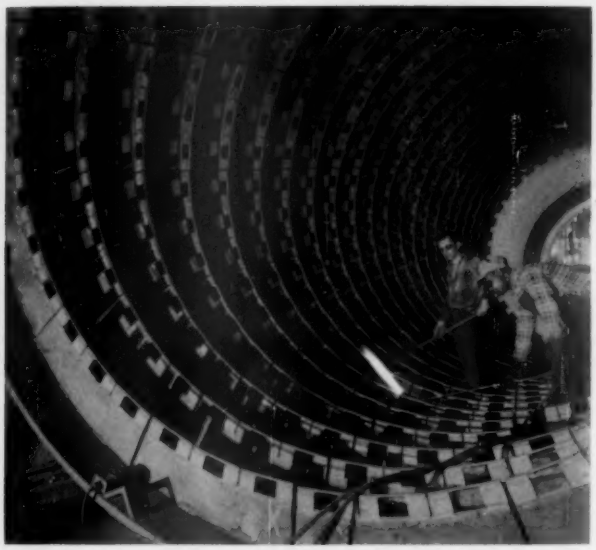
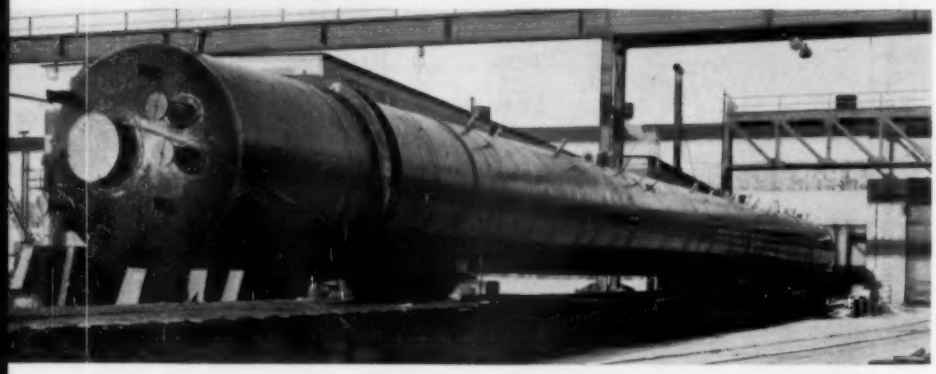
WELDING ZONES

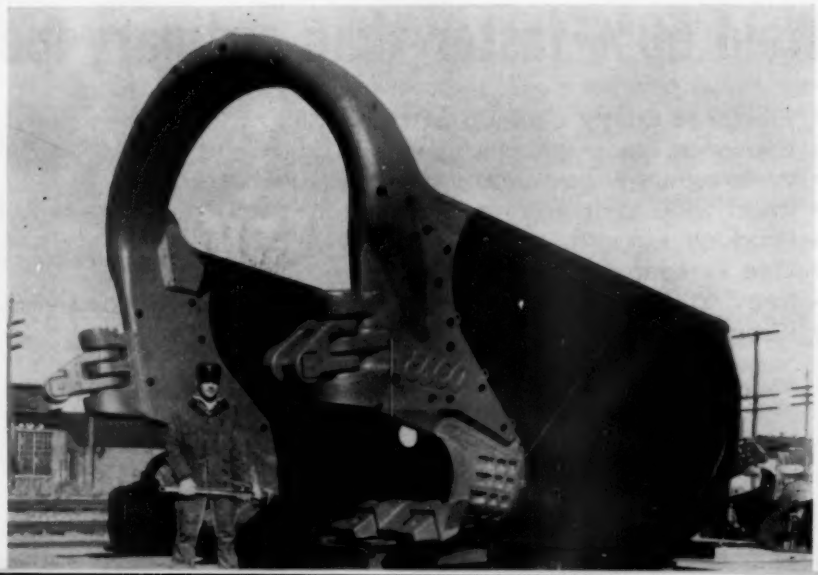
Stainless steel inserts for positioning fuel element nozzles in a nuclear reactor grid plate being welded at the Allis-Chalmers plant in Milwaukee



Welded dry process rotary kiln using a heat transfer chain of stainless steel designed to withstand up to 2000° F at the Superior, Ohio plant of Marquette Cement Co. (Courtesy Allis-Chalmers Mfg. Co.)



A 150-ft steel petroleum processing tower in Chicago Bridge & Iron Company's Chicago fabricating plant required three rail flat-cars for movement to customer



Big bucket that could dig a swimming pool in one bite. The 35-yard scoop, fabricated by dual-shield, semi-automatic welding, contains 5-in. thick steel plate. Constructed by the Esco Corp., Danville, Ill., the scoop will be used in a Brazilian open-pit mine. (Courtesy National Cylinder Gas Div.)

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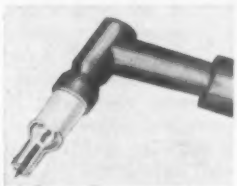
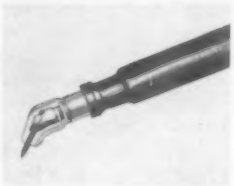
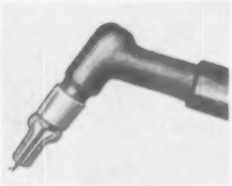


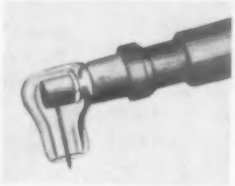
TEC Watercooled Angle Torch



TEC Watercooled Pencil Torch



TEC Aircooled Torch



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WORLD-WIDE WELDING NEWS

By Gerard E. Claussen

AUSTRIA

The Austrian journal *Schweisstechnik* for March 1960 describes spot- and seam-welding equipment for aluminum railway coaches. Instruments are described for measuring contact resistance and for recording current and pressure. MIL Specification W-6858A was used for inspecting the welds.

BELGIUM

The May 1960 issue of *Acier Stahl Steel* published by the Belgian Steel Information Center describes a heating chain for stress relieving welded joints in the field. The patented apparatus consists of resistors housed in grooved steatite plates hinged together to form a flexible belt or chain. The resistors provide a better electrical load than induction coils.

The April 1960 issue of *Acier Stahl Steel* presents a number of articles on structural welding. One describes the design theory for welded triangulated frameworks of steel tubing developed at the University of Naples. An elevated water storage tank—46 ft diam, 34-ft high—was welded at ground level, then was hoisted 100 ft to the top of a six-legged supporting structure in Belgium. Open-hearth steel was used for the reservoir. Secondary members were of a basic Bessemer steel. The magazine also contains photographs and a brief description of a sports arena in Madrid with eight welded arched girders—240-ft span, 31 ft high.

CZECHOSLOVAKIA

The Czech magazine *Zvaranie* for May 1960 consists of a series of articles celebrating the fifteenth birthday of the welding industry in Czechoslovakia. The Russian influence is emphasized. The June issue describes two low-hydrogen electrodes for a-c welding. The electrode whose coating contained 34% iron, 13% SiO_2 exhibited shallower fusion than the electrode whose coating contained 16% iron, 23% SiO_2. Another article shows that the pulsating bending fatigue strength of electroslag welds made under high restraint was 12,000 psi. Eliminating residual stresses by stress relief heat treatment or annealing raised the fatigue strength to 13,500–16,000 psi.

EAST GERMANY

The June 1960 issue of the East German magazine *Schweisstechnik* is a review of welding exhibits at the Leipzig Industrial Fair under the following headings: (1) Resistance welding (numerous machines described), (2) Arc welding power supplies, (3) Submerged arc equipment, (4) Gas shielded arc welding outfits, (5) Induction hardening, (6) Metal spraying, (7) Gas welding and cutting, (8) Filler metal, (9) Nondestructive inspection, (10) Welded chemical equipment, (11) Welded power plant, (12) Welded piping, (13) Welded cranes, (14) Welded earth movers, trucks and agricultural equipment.

FRANCE

The May–June 1960 issue of *Soudage et Techniques Connexes* contains the following general articles:

The fabrication of radar reflectors involved low-hydrogen electrodes for the high-tensile Cr-Mo tubing and argon metal arc welding for the aluminum alloy components. A mirror of stainless steel wires 0.079 in. diam required 7000 spot welds. The pressure was adjusted so that one wire penetrated halfway into the other.

On Feb. 12, 1960, the Committee on Thick Steel of the French Steel Manufacturers Technical Assn. held a meeting at Metz to discuss the bases on which specifications for weldable steel should rest. The Committee is divided into two parts. One part is concerned with structural sections; the other part deals with plates for naval, structural and pressure vessel applications. Three papers were read at the meeting. The first reviewed the cost factors in making low-carbon high-tensile steel. The second advocates as the basis of steel specifications a transition temperature with an associated energy to fracture low enough to be in the brittle area, yet high enough to be significant. The third pleads for consideration of higher carbon contents by designers. The lower cost of higher carbon steel is said to outweigh in many instances the added precautions of preheat and low-hydrogen electrodes, which are desirable for the lower-carbon steels in any event.

Based on the successful repair with aluminum bronze electrodes of a 12½ ton Francis turbine wheel made of brass (37 Zn, 2 Mn, 1.1 Al), it is proposed to cast the wheels henceforth in aluminum bronze to facilitate repairs on site. The Aluminum bronze electrode passed the Dutilleul and Luthy crack tests, the former consisting of a rigid fillet weld, and the latter of a bead deposited across the thickness of a stack of ten plates bolted together.

USSR

The April 1960 issue of the Russian magazine *Svarachnoe Proizvodstvo* contains the following articles:

1. For seam welding unequal thicknesses of stainless-steel sheet,

DR. GERARD E. CLAUSSEN is associated with Acrods Corporation, Sparrows Point, Md.

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for example 0.08 to 0.006 in. cadmium-copper wheels and single-phase, ignitron-controlled welders are suitable with or without condenser impulses. Spot frequency is 16 to 25 per sec, each lasting 0.004–0.006 sec. To weld 0.02- to 0.08-in. sheet, a step-by-step system is preferred, each spot requiring 0.12 to 0.30 sec. Molybdenum electrodes are recommended with a thin heat shield of molybdenum, beryllium-copper or stainless steel between the electrode and the thin sheet. The shield assists in localizing fusion at the sheet–sheet junction.

2. A battery power supply with graphite interrupter capable of delivering 300 cycles of 20,000 amp each per min without sparking is recommended for special spot-welding applications.

3. An examination was made of the welded rotor and cylinder of a gas turbine after 25,000 hr of service. The rotor was 22 in. diam and was made of steel containing 0.11 C, 0.88 Mn, 14.74 Cr, 12.53 Ni, 1.89 Mo, 0.86 Cb. The weld metal contained 0.14 C, 2.5 Mn, 15.5 Cr, 8.0 Ni, 3.5 Mo, 0.6 V. Before service the weld was stronger than the base metal. After service the weld had 10% elongation or less and the impact value fell to $^1/_2$ to $^1/_4$ of the initial value. The loss of ductility was attributed to the high ferrite content.

4. In a covered mild steel electrode whose covering contained 37% ilmenite, 21% Mn ore, 20% FeMn, 13% feldspar, a reduction in the content of starch and dextrine from 9 to 5% lowered the notch impact value of the weld by 10% but did not change its composition.

5. Insertion of an inductance in the circuit for CO_2 welding with 0.079-in. mild steel electrode at 25 v, 100–160 amp lowered spatter by a factor of 2.5.

6. The purity of CO_2 for welding varies during extraction of the gas from its 50-lb cylinder. If a pipe extends nearly to the bottom of the cylinder, the gas purity was high (99.6%) until only a few pounds of CO_2 remained. The purity then fell to 97.5%. If there was no internal pipe the purity was relatively low until all water had been drawn off. Welding grade CO_2 is specified to be 99.5% pure, the water content being 0.04% maximum.

7. Drawings are reproduced for two water-cooled Gooseneck Type CO_2 welding torches.

8. Automatic equipment is described for the field welding of butt joints on overland piping in any position. Two heads may be used simultaneously, both starting at the bottom and welding up to the top. The equipment for one head weighs 40 lb. The wire is 0.039 or 0.047 in diam.

9. Butt joints in stainless steel tubing $^5/_8$ in. diam, 0.59-in. wall were welded with tungsten arc and argon at 60 amp, 8 in. of weld per minute. The edges to be welded were flanged or upset. For mild steel tubing $^1/_2$ in. diam, 0.039-in. wall a consumable electrode is used at 40 amp with a 1:4 argon-CO_2 for backing.

10. Worn steel shafts containing 0.45 C were built up by CO_2 welding using mild steel wire. The deposit contained 0.20 C.

11. Automatic equipment was devised for tungsten-arc welding stainless steel tubing to plugs using argon. A circuit diagram is given.

12. Steam was used successfully as a shielding gas to deposit a mild steel electrode 0.079 in diam at 220 amp, 30 to 35 v. The deposit contained 0.08 C, 0.38 Mn, 0.11 Si and mechanical properties were good. The editor invited readers to comment on the practical application of steam.

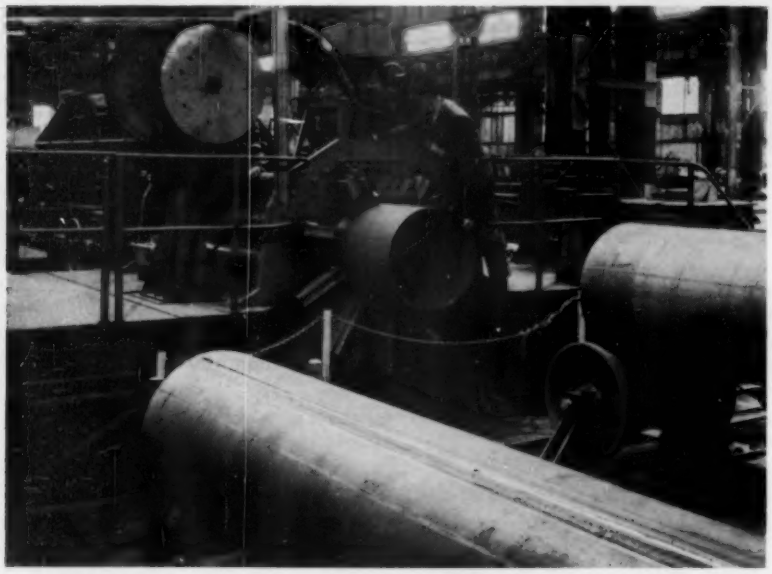
13. To reduce turbulence in the nozzle of a gas cutting torch, the passages were designed of constant width. The cutting speed for steel $^3/_{16}$ to $1^1/_2$-in. thick was increased 55 to 230%.

WEST GERMANY

A collection of twenty papers written by engineers of industries that consume welding and cutting equipment and products is published in the May 1960 issue of the West German *Schweissen und Schneiden*. Subjects treated in these papers are welded bridges, railway stations, dam gates, cranes, pipe line valves, locomotives, superheater tubing (oxyacetylene torch) and shell beams. Other topics are adhesive bonding in architecture, oxyacetylene pressure welding of concrete reinforcing bars, maintenance welding and flame hardening of marine engine piston rings.

Three of the papers deserve special mention. One describes the new IPE structural introduced a year ago. The new beams have ranges of uniform width which lend themselves more readily to cutting and butt welding than the old beams. Another paper describes welded railway tank cars for compressed gases. A fine-grained steel was used which contained 0.18 C, 0.45 Si, 1.25 Mn, 0.90 Cu, 1.00 Ni, 0.17 V, 0.40 Al, 95,000 psi tensile strength. Lime-base electrodes of Mn-Cu-Ni-Mo type were used. The tanks were stress relieved 45 min at 1110° F. Welded spherical storage tanks for liquids and compressed gases are the subject of the third paper. Design rules in Germany tend to be more liberal than in the United States with respect to the percentage of yield strength that is utilized. Aluminum-treated fine-grained steels are favored for high notch-impact value.

WEST GERMANY



Welding giant-size tubes in one of the plants of Phoenix-Rheinrohr A.G., Duesseldorf, West Germany

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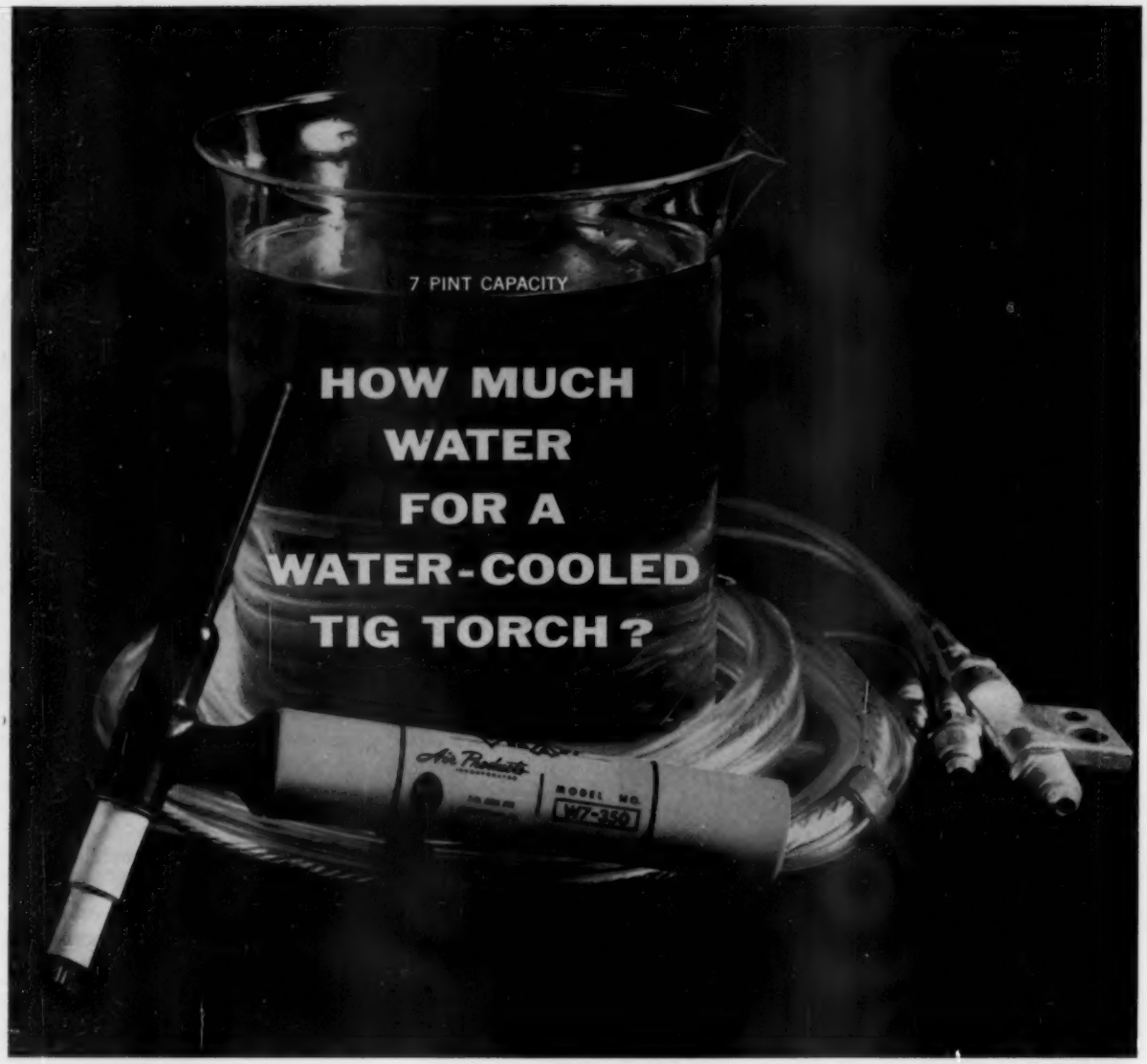

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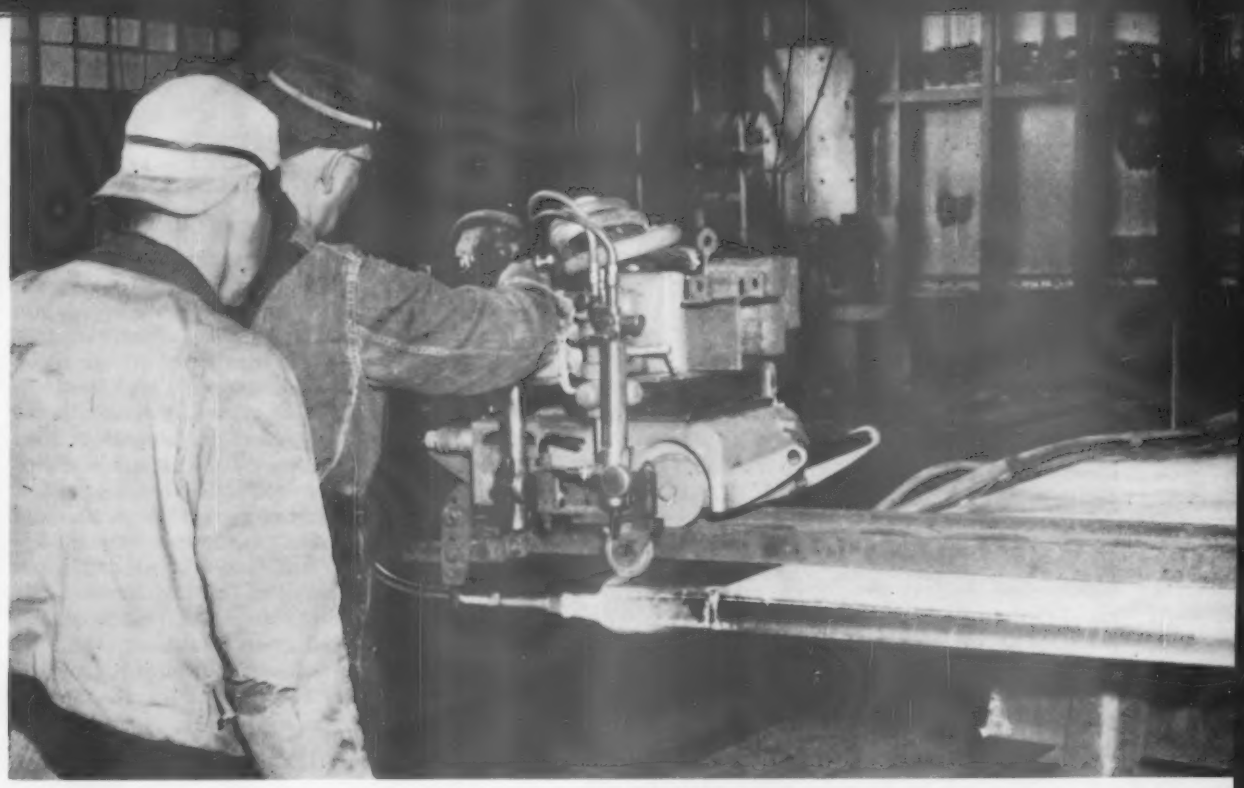


Beginning a single-pass production "J" groove in starting tab attached to $2^{3}/_{4}$-in. thick plate

Single-Pass "J" Grooving in Heavy Plate with an Oxy-Fuel Gas Flame

is a new process which reduces plate-edge preparation time on up to 4-in. thick plate by 70% and more

BY C. B. MILTON

At present, there are two widely accepted methods of preparing the edges of heavy plate for welding. These are "J" grooving and bevel-edge preparation. "J" grooving is often preferred because less filler metal is required in welding. This results in reduced operating times and lower costs.

Until very recently, machine planing has been the most successful method of preparing "J" grooves. However, this method has certain serious economical limitations. Large capital expenditures for equipment are required, and the low production rates associated with machine planing often result in production bottlenecks. Another "J" grooving method involves the use of flame machining. With this method, it has been possible to produce "J" grooves in plate up to $1^{1}/_{2}$-in. thick in two passes by following a bevel cut with a gouging pass. This method has had only limited acceptance, however, because of critical nozzle settings and the inherent instability of the gouging operation.

A new "J" grooving method described in this paper may now be utilized. This is "J" grooving with an oxy-fuel gas flame which is applied in a single pass to plates between $1^{1}/_{2}$- and 4-in. thick and to plates of greater thickness in a dual pass combination. Suitable preheat fuel gases include acetylene, propane and natural gas. This method is a new development and, based on production results, has the following advantages over "J" grooving with planing machines:

1. Low capital expenditures for equipment.
2. Lower direct costs.
3. Operating times, including set-up, which are 70 per cent (or more) less.

C. B. MILTON is Laboratory Division Head, Development Laboratory, Linde Co., Div. of Union Carbide Corp., Newark, N. J.

Paper presented at 1960 AWS National Fall Meeting held in Pittsburgh, Pa., Sept. 26–29, 1960.

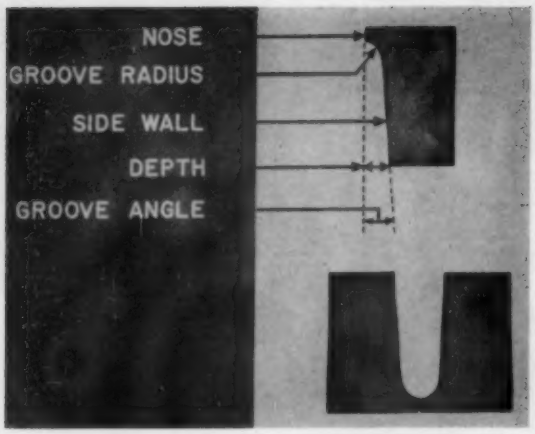


Fig. 1—Characteristics of single-pass oxy-fuel gas flame "J" groove

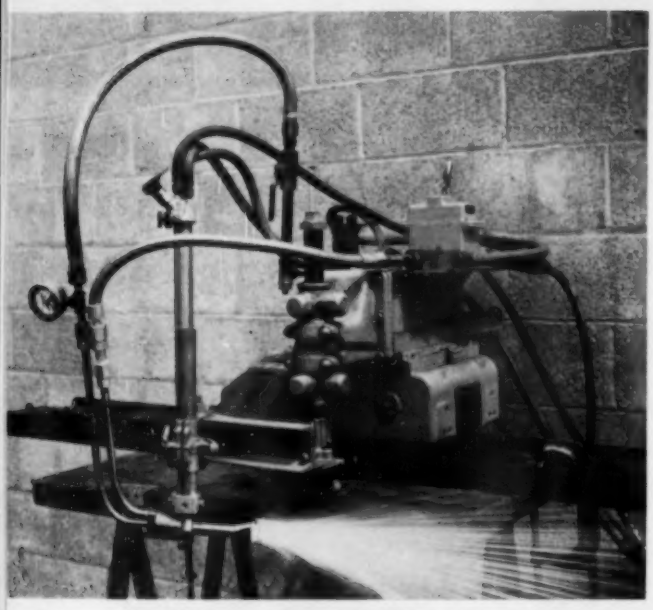


Fig. 2—Single-pass oxy-fuel gas flame "J" grooving installation for horizontal plate

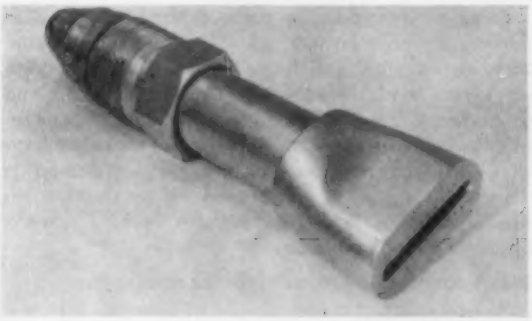


Fig. 3—Slotted nozzle for single-pass "J" grooving with an oxy-fuel gas flame

4. Ready location of plate defects.

Single-pass Flame "J" Groove Characteristics

With single-pass oxy-fuel gas flame "J" grooving, the desired "J" groove contour is produced repeatedly. The nose width and groove radius are maintained to specified dimensions—Fig. 1. Straight side-walls are produced to the desired groove angle, while the depth of the "J" groove is held constant.

Although no single "J" groove contour is most suitable for all welding applications, the new method can be used to produce most of the many and varied contours required in welding. The heat effect created by the "J" grooving reaction on the base plate is almost identical to that of straight-line oxy-fuel gas cutting—the heat-affected depth and hardness increases may be slightly less for "J" grooving because of the faster processing speeds. Development and production results, to date, have shown that any steel that can be oxygen cut can also be successfully flame "J" grooved.

Single-pass Oxy-fuel Gas Flame "J" Grooving Installation

A Machining Process

"J" grooving is a flame machining process, which may be applied to either horizontal or vertical plate as well as to circular forms. Successful and repetitive operations are dependent upon adherence to proper operating techniques and conditions. Variables that must be controlled include processing speeds, cutting oxygen and preheat gas flows, and nozzle angle and distance settings.

Equipment and Gas-flow Requirements

The first prerequisite for single-pass "J" grooving is an adequate installation. As shown in Fig. 2, the basic components of such an installation are a "J" grooving nozzle, an adequate gas supply, a nozzle positioning device, a plate follower, and a machine carriage to act as a motivating force. The machine carriage shown was specifically designed for use in oxygen-cutting operations, but any carriage capable of carrying the apparatus load that will provide constant and accurate speeds can be used. Examples would include side-beam carriages used in automatic welding and flame planers as utilized by steel fabricators.

The plate follower with its plate riding wheel is an integral part of the installation. This device continuously compensates for plate surface contours, making it possible to "J" groove plates which are not in a true plane. The nozzle positioning device is attached to and "rides" with the plate follower and constantly maintains the position of the "J" grooving nozzle relative to the base plate.

Gas flow requirements for processing 4-in. thick plate are 7000 cfh of oxygen and—depending upon the preheat fuel gas—210 cfh acetylene, 153 cfh propane or 288 cfh natural gas. As would be expected, gas flows of lesser magnitude are needed as plate thicknesses decrease.

"J" Grooving Nozzle

A close-up of the "J" grooving nozzle is shown in Fig. 3. In appearance, it is the same as any large oxygen-cutting nozzle except that the gas-exit end has been formed so that the cutting oxygen orifice is a long slot with a line of preheat ports along each side. As indicated in Fig. 4, the cutting oxygen flow passages are designed so that the cutting oxygen flows from the nozzle in a flat, elongated stream with a substantially constant velocity profile. This is the oxygen stream that produces a "J" groove suitable for welding.

If cutting-oxygen flows deviate too far from nozzle design flows, concentrations of flow will occur either at the ends of the slot or along the centerline of the nozzle. In the first case, the side wall will be convex and, in the latter, concave. Either condition could render the "J" groove unsuitable for welding. One should not attempt to vary the depth of the "J" groove by increasing or decreasing the cutting-oxygen flow. This dimension is controlled by the "J" grooving speed. Increased speeds give a lesser depth and decreased speeds result in a greater depth.

Control of Operating Variables

Operating Speeds and Gas Flows

Since the control of cutting speeds, cutting-oxygen flows and preheat gas flows is easily achieved, these variables are not a major concern of the "J" grooving operator. Most modern cutting machines have a speed indicator. The indicator should be calibrated, however, to assure use of the correct cutting speed.

There are two suitable methods for controlling cutting oxygen flows. First, a flowmeter can be installed in any convenient point in the cutting oxygen supply system. Second, a pressure gage can be used as a flow indicator, providing it has been calibrated against a flowmeter after installation in the flow system.

"J" grooving requires high preheat gas flows. Although it is not necessary to measure these flows as absolute quantities, the flows should be the maximum obtainable through the nozzle without "blow-off."

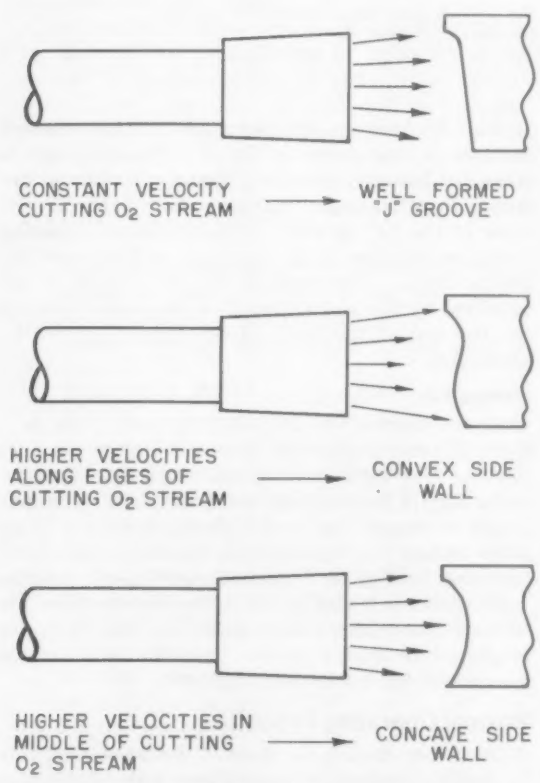

CONSTANT VELOCITY CUTTING O_2 STREAM
WELL FORMED "J" GROOVE
HIGHER VELOCITIES ALONG EDGES OF CUTTING O_2 STREAM
CONVEX SIDE WALL
HIGHER VELOCITIES IN MIDDLE OF CUTTING O_2 STREAM
CONCAVE SIDE WALL

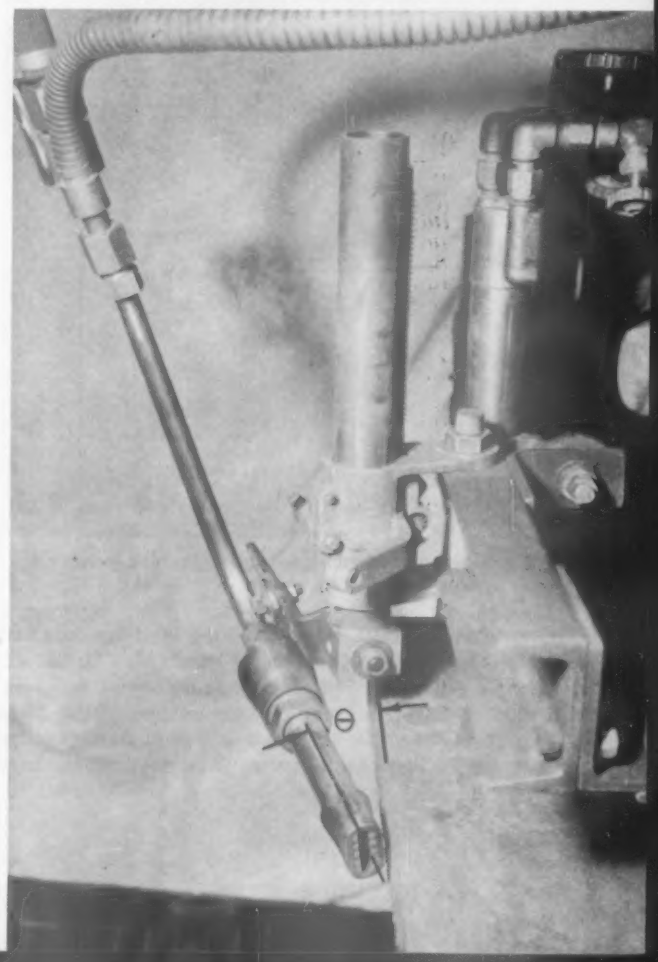
Fig. 4—Behavior of slotted nozzle

Nozzle Positioning

Four variables are encountered when positioning "J" grooving nozzles. These are (1) the impinging angle, (2) the lateral angle, (3) the slot angle and (4) the slot distance. Although the variables are not super-critical, care should be practiced when setting them. A machinist's protractor is suitable for measuring the three nozzle angles and the slot distance.

As shown in Fig. 5, the impinging angle (θ) is

Fig. 5—Nozzle positioning for impingement angle



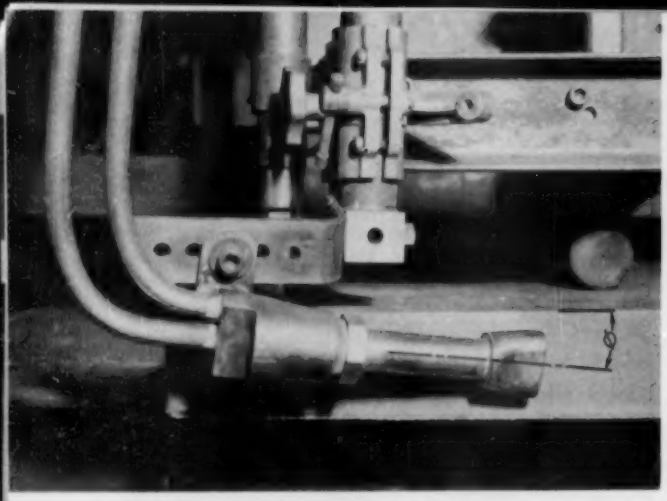


Fig. 6—Nozzle positioning for lateral angle

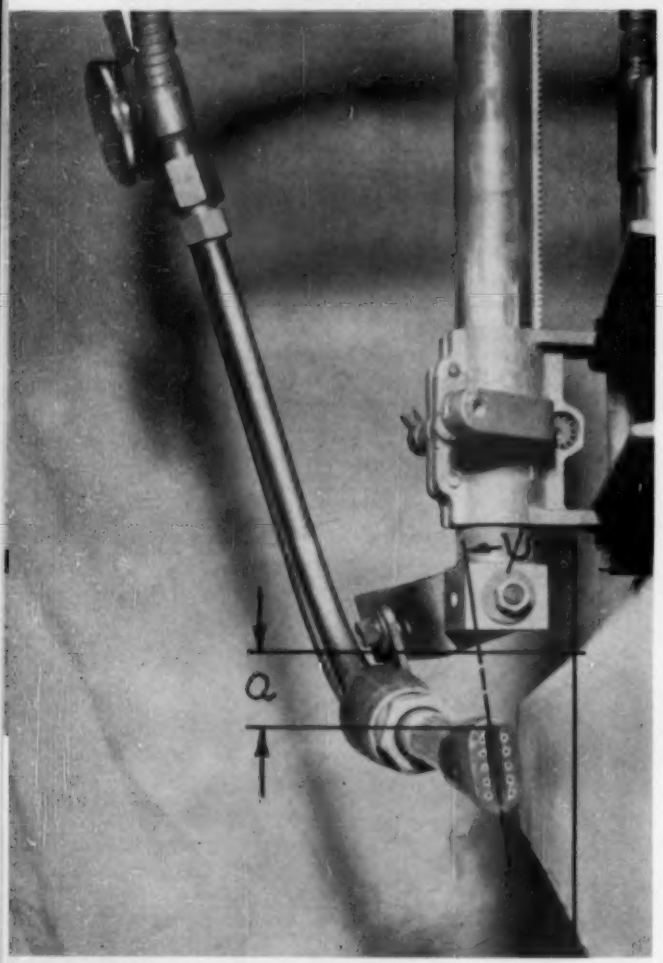


Fig. 7—Nozzle positioning for slot angle and distance

measured between the centerline of the nozzle and the edge of the plate to be "J" grooved. The lateral angle (ϕ) is the downward angle between the centerline of the nozzle and the corner line of the plate edge as shown in Fig. 6; it is this angle that helps direct the flow of hot process slag away from the nose

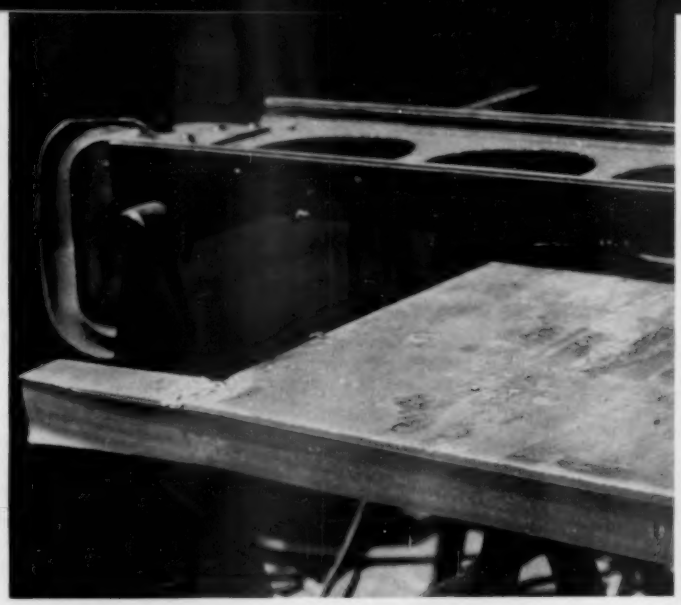


Fig. 8—Starting tab (attached to left portion of "J" grooved plate)

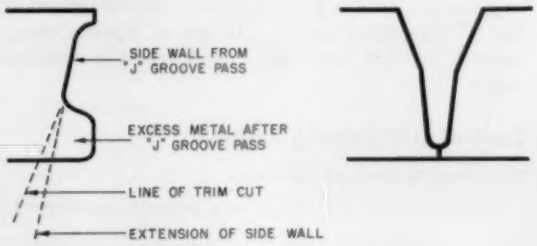


Fig. 9—Two-pass technique of "J" grooving followed by oxygen cutting

of the "J" groove. The slot angle (ψ) and the slot distance (a) are shown in Fig. 7. The slot angle is measured between the side of the nozzle slot and the face of the plate edge; it largely controls the groove angle of the "J" groove. Within process operating limits, an increase in the slot angle will increase the groove angle. The nose of the "J" groove is determined by the slot distance as measured between the top end of the slot and the top corner of the plate edge.

Starting Tab

At the start of a "J" grooving pass, there is a short distance before the groove assumes its final contour and depth. It is, therefore, necessary to use a lightly tack-welded starting tab of sufficient length to ensure that a full-depth groove is being made before the base plate is reached. This is illustrated in Fig. 8. Typical starting-tab lengths vary between 8 and 12 in. The shorter tabs are used for the thinner plates, while the longer tabs are employed for thicker plates. Once the "J" groove is completed, the tab is easily removed.

Normal Operating Procedure

Operators should be trained before attempting to begin production operations with single-pass

Table 1—Operating Conditions for Single-pass Oxy-fuel Gas Flame "J" Grooving

Plate thickness, in.	Cutting oxygen flow, cfh	"J" grooving speed, ipm	Impinging angle, θ, deg.	Lateral angle ϕ, deg.	Slot angle ψ, deg.	Slot distance a, in.
1 1/2	1650	44	15	4	2	7/16
2	1450	24	18	4	4	1/2
2 1/2	4300	40	18	4	4	5/8
3	5000	27	15	2	4	1/2
3 1/2	5000	27	15	2	4	1/2
4	7000	27	18	2	8	1

Table 2—Gas Consumptions and Weld Areas for Single-pass Oxy-fuel Gas Flame "J" Grooving

Plate thickness, in.	Groove cross section area,[a] sq in.	Total gas consumption, cu ft per linear ft of "J" groove					
		Oxygen	Acetylene	Oxygen	Propane	Oxygen	Natural gas
1 1/2	0.375	7.9	0.35	8.2	0.22	7.9	0.27
2	0.650	13.4	1.26	14.0	0.66	13.2	1.00
2 1/2	0.900	22.1	1.26	22.9	0.66	22.6	1.00
3	1.35	38.6	1.56	40.5	1.13	39.9	2.13
3 1/2	1.65	38.6	1.56	40.5	1.13	39.9	2.13
4	2.20	53.5	1.56	55.3	1.13	54.7	2.13

[a] Weld area = 2 × groove area.

flame "J" grooving. This procedure can serve two purposes. First, it permits the operator to gain confidence in the setting of the various variables. Second, it makes it possible to determine and record operating conditions for any special "J" groove contour which might be desired and may vary from those described in this paper.

Operating conditions and variables for 1 1/2- to 4-in. thick plates are tabulated in Table 1 and will produce "J" grooves with a 3/16- to 1/4-in. nose, a 3/8- to 3/4-in. groove radius, and a 5- to 7 1/2-deg. groove angle. The larger dimensions are for the thicker plates.

The proper operating sequence for straight-line "J" grooving a selected plate thickness would be as follows:

1. Cut the plate to size, making certain that plate edges are perpendicular to the plate faces.
2. Select proper "J" grooving nozzle.
3. Tack weld the starting tab to the starting edge.
4. Place the machine track parallel to plate edge.
5. Set the cutting oxygen flow according to recommendations in Table 1.
6. Adjust the machine carriage speed.
7. Set the impinging angle (θ), the lateral angle (ϕ) and slot angle (ψ).
8. Adjust the slot distance (a). (The nose width can be varied by adjusting the slot distance, the sidewall angle by adjusting the slot angle, and the "J" groove depth by regulating the carriage speed.)
9. Provide minimum clearance between the nozzle and plate edge.
10. Set the preheat gases to produce the maximum stable flames.
11. Preheat the starting tab edge until it is molten.
12. Open the cutting-oxygen valve slowly and smoothly while starting the machine.
13. Unlock the plate follower wheel as it begins to ride the plate.
14. Lock the plate follower wheel just prior to leaving the plate at the completion of the cut.
15. Remove the starting tab—the "J" groove is completed.

When using the data previously presented in Table 1, it is possible to estimate "J" grooving operating costs and to predict the subsequent welding requirements. Calculations based on known gas flows, processing speeds and "J" groove cross-sectional areas are shown in Table 2. Total gas costs can be determined by applying current price schedules to the gas consumptions. Welding time, weld metal and flux consumption requirements likewise can be estimated. (It should be noted that the "weld area" in Table 2 is twice the "J" groove area. The "weld area" is formed when two "J" grooves are placed in welding position. A similar table can be compiled for special "J" grooves that would be produced from operating conditions other than those of Table 1.)

Technique Variations

Supplementary Use of Oxygen Cutting

Discussion up to this point has been directed toward the production of single "J" grooves in a single pass which, as stated previously, is limited to plates of a maximum 4-in. thickness. Thicker plates can be "J" grooved by utilizing a two-pass technique whereby a standard "J" grooving pass is followed by a cutting operation as shown in Fig 9. Standard operating conditions for processing 4-in. thick plate will produce the desired nose, groove radius and groove angle but will leave a

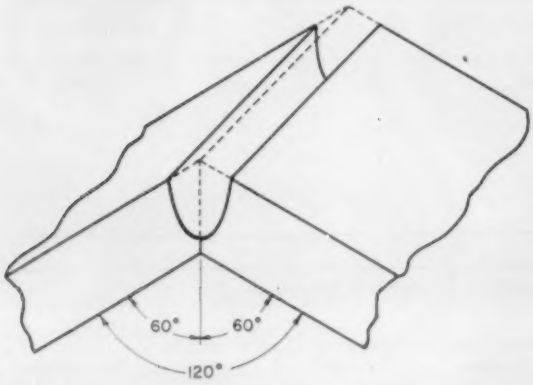


Fig. 10—"J" groove at an angle in plate

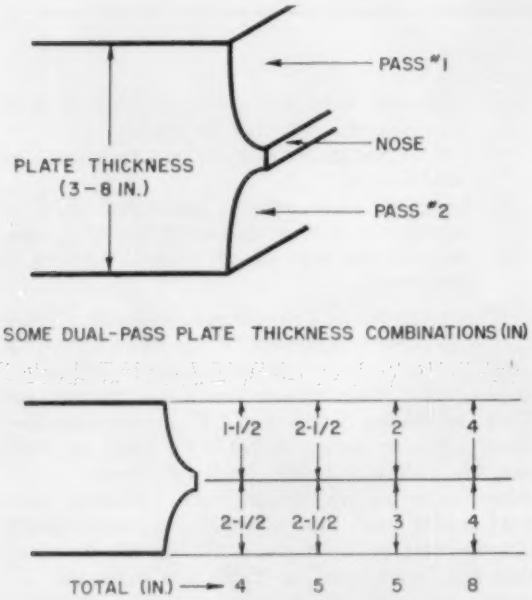


Fig. 11—Dual-pass technique for producing two "J" grooves with a common nose

line of excess metal along the lower edge of the plate which can then be removed by oxygen cutting. Care should be taken to be sure that the angle of cut is slightly greater than the groove angle. This permits the cut to "break into the clear" without gouging the sidewall.

Angling

As previously indicated, plate edges should be cut perpendicular to the plate faces when cutting the plates to size. This is a requirement to produce "J" grooves repeatedly since the resulting groove angle is always relative to the face of the plate edge. "J" grooves thus produced on square-cut edges are for in-line butt welds. There are many occasions,

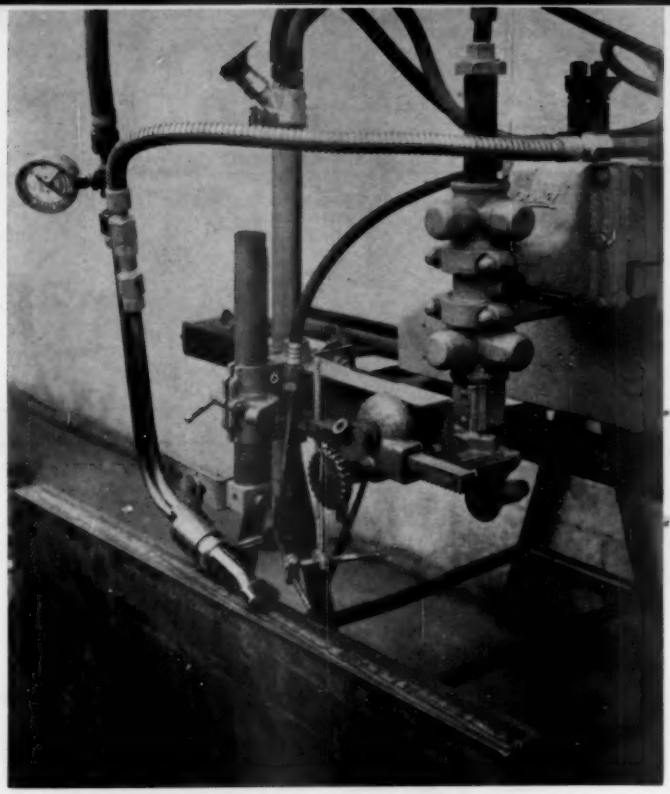


Fig. 12—Single-pass oxy-fuel gas flame "J" grooving setup for vertical plate (note air jet adjacent to slotted nozzle)

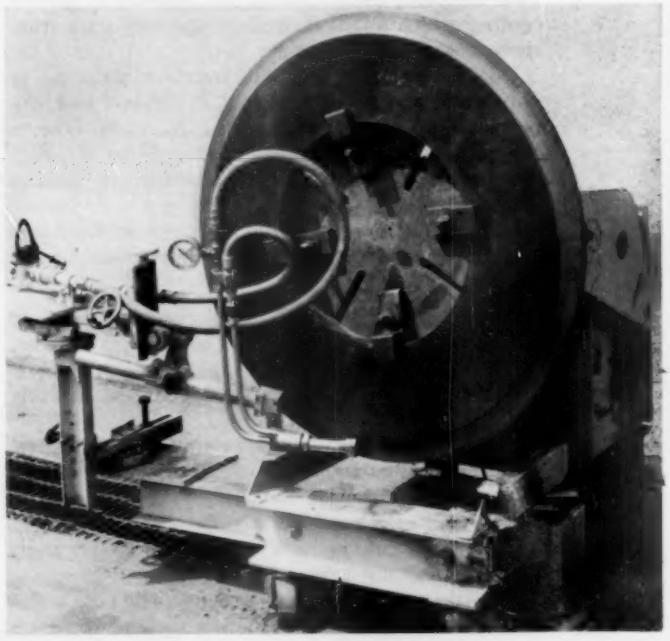


Fig. 13—Installation for single-pass circumferential "J" grooving with oxy-fuel gas flame

however, when the welds are made at an angle as shown in Fig. 10. Suitable "J" grooves can be prepared by cutting the plates at angles equal to $^1/_2$ the weld angle. Standard operating conditions will still apply, because all nozzle positioning variables still remain relative to the plate edge face.

Double "J" Grooves with Common Nose

It is often desirable that the nose section be within the plate and common to two "J" grooves rather than along one edge of the plate face. A double "J" groove combination is shown in Fig. 11. As may be noted, various double single-pass combinations can be utilized in plates from 3- to 8-in. thick. In this case, it is necessary to turn the plate over after making the first groove and prior to making the second one. The double "J" groove combination can be extended beyond 8 in. by employing the two-pass technique previously illustrated in Fig. 9.

"J" Grooving of Vertical Plate

Early in the development of single-pass flame "J" grooving, it became evident that the ability to process the top edges of plates in a vertical position would at times be most desirable. This is particularly true, for example, when "J" grooving the longitudinal edges of plates that have been formed into semicircular half-shells for fabrication into heavy-wall pressure vessels. The ability to process vertical plates has made it possible to place a half-shell horizontally with the two edges turned upwards and to "J" groove both edges without rehandling.

When "J" grooving horizontal plate, gravity pulls the molten slag down and away from the nose section and thereby permits the attainment of a straight, uniform nose line and a constant root radius. When processing vertical plate, however, the effect of gravity for slag removal is lost. To compensate for this loss, an air jet is employed as shown in Fig. 12. Its positioning is not critical. Its downward angle should be approximately the same as the impinging angle of the nozzle. The air stream should impinge on the nose corner of the plate edge at a cross angle of approximately 15 deg. The distance "e" between the nozzle and air jet should be such that the air stream engages the slag puddle slightly ahead of the reaction zone. The air stream blows away the slag and prevents nose damage without interfering with the reaction.

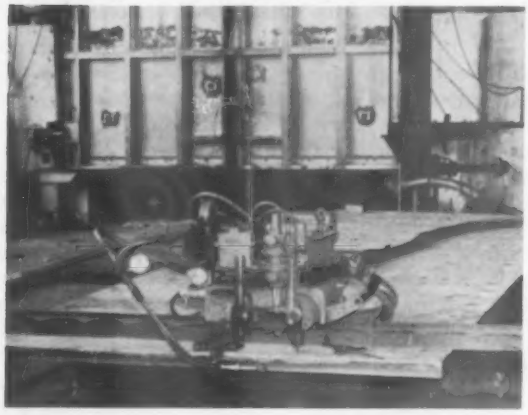


Fig. 14—Production installation for "J" grooving of $2^3/_4$-in. thick plate

Circular "J" Grooving

Another time-saving application for single-pass "J" grooving is in the preparation of circular pressure-vessel drum ends and end caps. That this can be readily achieved in one revolution of the drum or cap is illustrated in Fig. 13. In this application standard conditions are maintained except that the nozzle remains in a fixed position while the workpiece is rotated at a circumferential speed equal to the recommended carriage speed.

On circular "J" grooving applications it is evident that a starting tab as previously described cannot be used. However, starts can be made in two ways.

Fig. 15—Single-pass oxy-fuel gas flame "J" grooving in $2^3/_4$-in. thick plate—seen from ahead of advancing slotted nozzle

The heat of the burning preheat gases can be utilized to melt a steel rod such as a gas welding rod so as to create a line of molten metal in front of the nozzle. When the cutting oxygen is turned on, a start results. Starts can also be made with powder, making use of commercially available iron powder attachments commonly used by steel producers for powder-scarfing stainless steel.

Again, there is a certain distance before the "J" groove assumes its final depth and contour. It is necessary, therefore, to allow the workpiece to rotate a few degrees beyond one revolution. This has the effect of allowing the second pass to remove the excess metal remaining from the initial start. The reaction should be stopped just before the full depth and contour of the start are reached. A small line of excess metal will remain but can be easily removed by grinding.

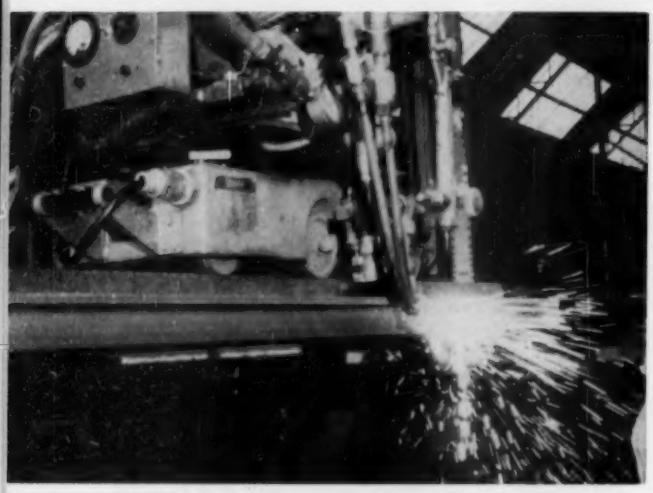


Fig. 16—Single-pass oxy-fuel gas flame "J" grooving in $2^3/_4$-in. thick plate—seen from behind advancing slotted nozzle

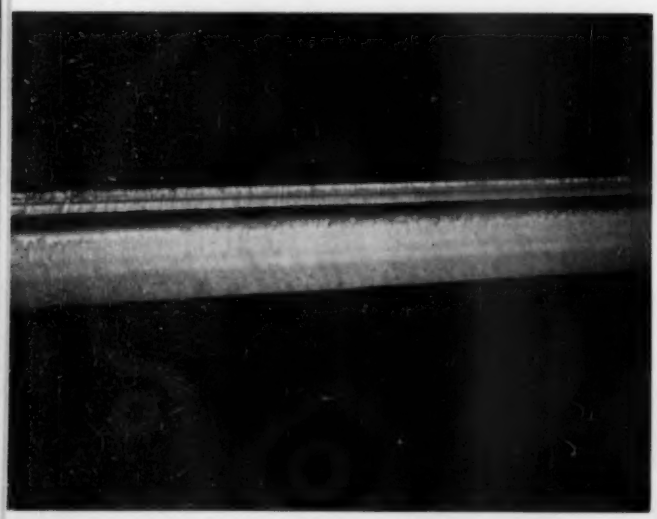


Fig. 17—Final single-pass oxy-fuel gas flame "J" groove in $2^3/_4$-in. thick plate

Production Examples

Use on a production basis has proved that single-pass "J" grooving with an oxy-fuel gas flame is practical and economical. Furthermore, it is entirely suitable for high-quality welding. As an example of its use, steps in its application to $2^3/_4$-in. thick plate are shown in Figs. 14 through 17 and in the lead photograph. In this example, total processing time—including set-up and handling time—was only 2 hr compared with six to eight hours normally required for mechanical "J" grooving with a machine planer.

In the example cited here, the plate was previously cut to approximately $4^1/_2$ by 15 ft. In Fig. 14, the "J" grooving installation has been positioned on the plate and all operating variables have been adjusted. Preheating of the starting tab preparatory to starting the "J" grooving pass is shown in the lead photograph.

Fig. 16 shows "J" grooving in action from ahead of the cutting reaction zone, while Fig. 17 shows the same operation behind the reaction zone. In this example, "J" grooving is proceeding at 40 ipm, using 4300 cfh of oxygen; the nose is clearly visible. The final "J" groove is shown in Fig. 18 and has a $^3/_8$-in. nose, a $^1/_2$-in. groove radius, and a 7-deg groove angle. The groove has a very smooth surface, which is suitable for welding. Furthermore, any plate laminations or inclusions are readily visible and are not smeared over as may occur with "J" grooving using a machine planer.

Summary

Single-pass "J" grooving with an oxy-fuel gas flame is practical and economical for application to the edges of plate ranging in thickness from $1^1/_2$ to 4 in. Moreover, "J" grooves can be produced with a single pass in both horizontal plate and the top edges of plates in a vertical position; the process is also applicable to circular plate edges as encountered in thick-walled pressure vessels.

The range of the process can be extended beyond 4 in. by utilizing double "J" grooves sharing a common nose or by a two-pass technique whereby excess metal from the "J" grooving pass is removed by oxygen cutting. Heat-affected depths and hardnesses are no greater than encountered in oxygen cutting. Experience to date indicates that single-pass "J" grooving with an oxy-fuel gas flame is applicable to any steel that can be oxygen cut.

Specially designed "J" grooving nozzles are available for use with acetylene, propane or natural gas. Nozzle and operating-variable adjustments are easily made by the operator. Time requirements—including set-up and handling—are 70% (or more) less than those necessary for machine planing. Resulting "J" grooved surfaces are smooth and tear-free; they readily reveal plate defects such as laminations and inclusions.

T-95 tank hull with ferritic welded hull

Development of electrodes and significance of Army "H" plate test is described in

Ferritic Welding of Steel Armor

BY Z. J. FABRYKOWSKI

The contents of this paper have been reported and discussed at various meetings of the Ordnance Advisory Committees and the American Ordnance Association. This paper has been prepared with the view of presenting this information for public dissemination in the hope that it may be found useful for industrial application, particularly in connection with high-strength steels.

Why ferritic welding? This is a question which logically arises at this point. In answer, there are four reasons:

1. To conserve critical alloys.
2. To improve ballistic performance.
3. To reduce cost.
4. To increase rate of production.

Certain basic problems are involved in ferritic welding in that an increased level of technical and shop "know-how" must prevail, greater attention to processing details is required, and the addition of preheating equipment is generally needed.

Development of Ferritic Electrodes

The development of a ferritic electrode low in alloy content for application to military vehicles was initiated during World War II. The project was conducted under the jurisdiction of the National Defense Research Committee and resulted in the development of a low-hydrogen, high-strength electrode of a manganese-molybdenum type. This was known as the NRC2A electrode and brought into existence Specification AXS-1450.

The development of the NRC2A electrode was timely, since the production of large armor castings necessitated repair by welding in order to salvage castings containing huge tonnages of critical alloy steel. This electrode permitted repair welds in the as-welded condition and responded to various heat treatments. A considerable amount of development work in the application of the NRC2A electrodes for joining purposes was also explored with limited success. One great disadvantage was related to the high preheat (in excess of 300° F) required. The ballistic results, however, were impressive.

At the end of World War II, a contract was placed by Army Ordnance to continue the development of ferritic electrodes. At the same time, the Navy organized an industrial committee of electrode manufacturers to pursue development of ferritic electrodes for Navy use.

The Navy industry development resulted in Specification MIL-E-986 during the Korean emergency. Concurrent with the issuance of the specification, development work was continued by Ordnance to evaluate the application of the new Grade 230 and 260 electrodes to military vehicles—Table 1.

Through extensive industry-ordnance development and Aberdeen Proving Ground testing at ambient and sub-zero temperatures, it was found that the Grades 230 and 260 were ballistically comparable and better than either the NRC2A or

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austenitic types. It was the recommendation of the Ordnance Advisory Committee on the Welding of Armor that Grade 230 be used for joining purposes. Its introduction on a production basis for joining armor began during the Korean emergency with the T98 vehicle at American Car and Foundry, followed by the M59 and M84 at Food Machinery and Chemical Corp., the M42 at Cadillac Tank Plant and M50 at Allis Chalmers. Production results on these vehicles, which reflected armor thicknesses up to 1 in., were satisfactory.

Experience in employing ferritic electrodes in these constructions resulted in improving "know-how" and, equally important, in gaining confidence for ferritic application.

The Army "H" Plate Test

Success in the use of ferritic electrodes in the T95 medium tank development program is based on the use of the Army "H" plate test. The following type questions are usually generated in connection with this test:

1. What is the Army "H" plate test?

It is primarily a qualification test used in production. It is also employed for research purposes. The size and other dimensional features are indicated in Fig. 1.

2. What is the purpose of the "H" plate test?

(*a*) To demonstrate that the required level of welding quality resulting from the application of a specific welding procedure can or cannot be obtained as determined by radiography.

(*b*) When the required degree of quality is obtained, its subsequent purpose is to demonstrate whether the weldment is acceptable as judged by ballistic shock testing based on maximum length of weld joint cracking.

3. Why is the "H" plate test a desirable test?

(*a*) It reflects the fabrication of a weld joint under high restraint.

(*b*) It contains a weld joint arrangement which lends itself to various positions of welding.

(*c*) A better evaluation of secondary equipment used for processing weld joints such as grinding, chipping and gouging is available.

Table 1—Comparison of Electrodes

Covered electrodes	Low hydrogen	Carbon in core wire, %, max	Major alloys in coating?	Moisture, %, max	Minimum yield strength, psi
NRC2A[a]	Yes	0.17	Yes (Mn) No (Mo)	[c]	80,000
Grade 230[b]	Yes	0.10	Yes (Ni-Mo-V)	0.24	90,000
Grade 260[b]	Yes	0.10	Yes (Ni-Mo-V)	0.24	110,000

[a] Old Specification AXS-1450.
[b] New Specification MIL-E-986.
[c] Control of moisture not required by specification.

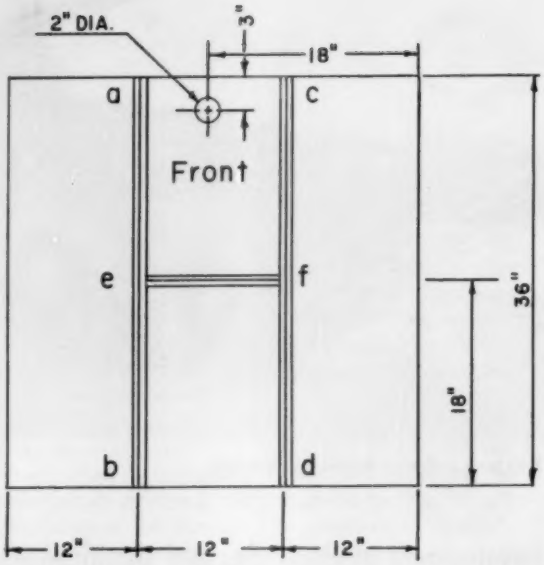


Fig. 1—Army "H" plate

(*d*) Is of a size that provides for a better understanding of temperature control during welding.

(*e*) A significant amount of joint length is contained to better evaluate joint soundness.

(*f*) The test highlights the importance of crater cracks and proper use of back-up material.

(*g*) It permits evaluation of angular distortion.

(*h*) Because of the size of test plate, the evaluation of tack weld blocks is permitted.

(*i*) A means is provided to evaluate shrinkage and the differences in edge preparation.

(*j*) A desirable target is presented for ballistic shock testing.

Summarizing, the "H" plate is an aid for gaining "know-how," preparing an organization for welding, "difficult to weld materials" and to recognize the need of stringent controls. The term Army "H" plate is suggestive to welding armor materials. Since armor is a high-strength material, there is no reason why the "H" plate cannot be used with advantage for development of welding procedures and evaluation of high-strength materials for industrial application—at least that aspect which has to do with joining and not destructive testing by ballistic impact.

T95 Ferritic Welding

Development of Ferritic Welding Procedure

Three T95 hulls as illustrated in the lead photograph—Nos. 7, 8 and 9—were welded with Grade 230 ferritic electrode with outstanding success. Hulls 1–6 were welded with austenitic electrodes. Joints of the complete penetration type were used for the so-called ballistic joints. The ballistic joints are those which join the various cast and rolled armor

pieces making up the outer hull configuration. All hulls were welded at OTAC facilities.

It was planned to start the fabrication of the hulls with ferritic electrodes when the required "H" plates were fabricated satisfactorily from a welding point of view as judged by radiographic examination. These plates, however, would be tested ballistically to ascertain their performance.

In fabricating the "H" plates, difficulties were experienced and the proposed procedure was modified accordingly. The difficulty of greatest concern was related to transverse cracking of great proportions in the cast material touching the toe of the weld—Table 2.

Welding Ballistic Joints

The "H" plate experience led to the requirement of procuring hull castings with a maximum carbon of 0.30% and tempered after flame cutting the weld edges. A carbon check revealed that Hull No. 7 (H No. 8350) was 0.30%, Hull No. 8 (H #8350) was 0.28%, and Hull No. 9 (H #8278) was 0.30%. Carbon in rolled plates for hulls varied from 0.23 to 0.30%.

The moisture content of $^{3}/_{16}$-in. diam electrodes used for flat position hull welding, as supported by electrode supplier affidavits and moisture check, was less than 0.25%. A higher moisture content in $^{1}/_{8}$-in. diam electrodes was revealed by a moisture check. These were used, however, for a small amount of vertical position welding without any problems.

Based on experience gained in making "H" plates, which were prepared not for the purpose of complying to a specification but for the purpose of developing a procedure and gaining "know-how" for welding T95 hulls, fabrication of hulls began.

For ferritic hull welding, a preheat of 150° to 175° F and interpass between 150° and 225° F was established and employed. Once the welding was begun at the preheat temperature, the weld joint was not permitted to drop below 150° F until it was completed. The weld toes were radius ground while at the interpass temperature range—Fig. 2.

For preheating and maintaining interpass temperature, a $^{1}/_{8}$-in. diam alloy wire heated by the resistance to current derived from a welding machine was used on all ballistic joints. In addition, radiant strip heaters connected to electrical outlets in the shop were used in certain heavy joint locations.

Welding Attachments

Some important attachments, such as hold downs, tow lugs, lifting eyes and towing pintles, were welded with ferritic electrodes on Hull Nos. 8 and 9. All other attachments on Hulls 7, 8 and 9 were welded using austenitic electrodes.

Ferritic welding of the first attachments was performed with difficulty. This difficulty was related to longitudinal cracking at the toe of the weld, as evidenced by dye penetrant examination. Although arrangements were made to eliminate the presence of cracking, it did not seem a practical application. The decision was made to change to austenitic electrodes for all attachments. It appears difficult to justify the use of ferritic electrodes for welding attachments in the T95 vehicle construction because of high level of care, supervision, inspection vigilance and "know-how" required, as compared to the small quantity of austenitic electrodes needed for welding attachments.

Non-destructive Examination

All ballistic joints were examined by dye penetrant inspection. This was done after each pass and after completion of each weld joint. The developer used for dye penetrant examination evaporated instantly on contact under the interpass temperature conditions used. In order to retard this evaporation, the liquid was separated from the white pigment and substituted with water.

Table 2—Welding and Ballistic Results of $1^{1}/_{2}$-in. "H" Plates

PL No. and welding position[a]	Material and heat No.	Weld edge[a]	Preheat, °F	Interpass, °F	X-ray, findings[b]	Ballistic, results
95-1 V	DB15092-2-1 rolled	F.C.	125	150	O.K.	O.K.
95-2 F	DB15092-2-1 rolled	F.C.	125	150	8 T.C.	...
95-3 F	DB15092-2-1 rolled	F.C.	150	175	O.K.	Fails
95-4 V	6611 cast	F.C.	150	175	O.K.	Fails
95-5 F	6422 cast	F.C.	150	175	27 T.C.[d] 3 L.C.	...
95-5 F reweld	6422 cast	M	150	175	3 T.C. 3 L.C.	...
95-6 F	6239 cast	F.C.	150	175	O.K.	O.K.
95-7 F	8716 cast	F.C.-T F.R.-T[c]	150	175	O.K.	O.K.
95-8 F	8350 cast	F.C.-T F.R.-T[c]	150	175	O.K.	O.K.

[a] V = vertical; F = flat; M = machine; F.C. = flame cut; F.C.-T = flame cut and tempered; and F.R.-T = flame recut and tempered.
[b] T.C. = transverse cracks; L.C. = longitudinal cracks; and O.K. = acceptable by X-ray and penetrant examination.
[c] Recut and tempered for better alignment of vertexes.
[d] Penetrant examination revealed over 50 T.C.

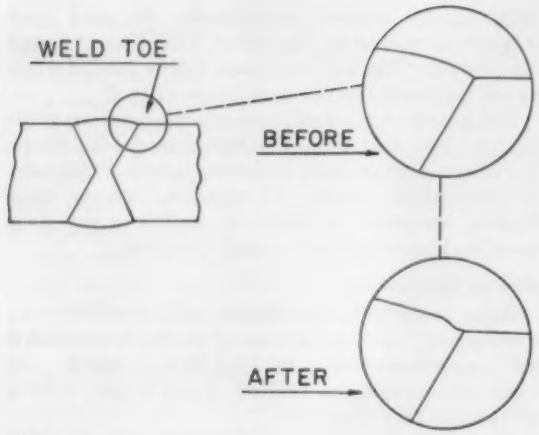


Fig. 2—Toe grinding

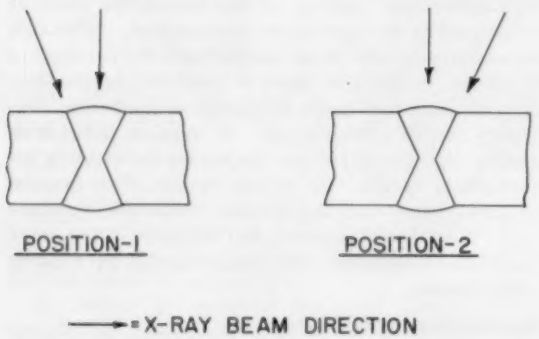


Fig. 3—Stereo radiography

Table 3—Radiographic Results of Ballistic Joints[a]

Radiographic quality standards[b]	Number of positions: Aust. hull 5	Aust. hull 6	Fe hull 7	Fe hull 8	Fe hull 9
Sound positions	35	56	89	77	81
Std. 1 positions	17	14	2	10	6
Std. 2 positions	1	5	0	1	2
Std. 3 positions	10	4	0	0	0
No std. positions (fusion defects)	23	5	0	1	1
No std. positions (cracks)	3	5	0	2[c]	1[d]
Total positions	89	89	91	91	91

[a] Based on 1,000,000 v, X-ray machine.
[b] Sound = highest quality obtainable; Standard 3 = lowest weld quality acceptable; No std. = quality not acceptable.
[c] Longitudinal cracks (improper grinding of weld toes).
[d] Transverse crack.

Table 4—Radiographic Results of Bump Stops

Lowest radiographic quality in any bump stop location	Number of bump stop locations: Aust. hull 6	Fe hull 7	Fe hull 8	Fe hull 9
Sound	0	0	2	1
Std. 1	1	4[c]	2	2
Std. 2	0	0	0	0
Std. 3	0	0	0	0
No std.	3[b]	0	0	1[a]

[a] 6 in. fusion defect.
[b] All cracks 1 1/8, 1 1/2 and 4 1/2-in. long.
[c] Some rewelded three times. (Severe cracking)

All weld joints on the hull were 100% radiographed. Joints containing a plate or casting thickness greater than 1 in. were radiographed in each position twice. One radiograph would reflect an X-ray beam path normally employed, while the other would be parallel to a joint bevel. In the adjacent position, one radiograph would again reflect a normal X-ray beam path, but this time the other would be parallel to the joint bevel on the other side—Fig. 3 and Table 3.

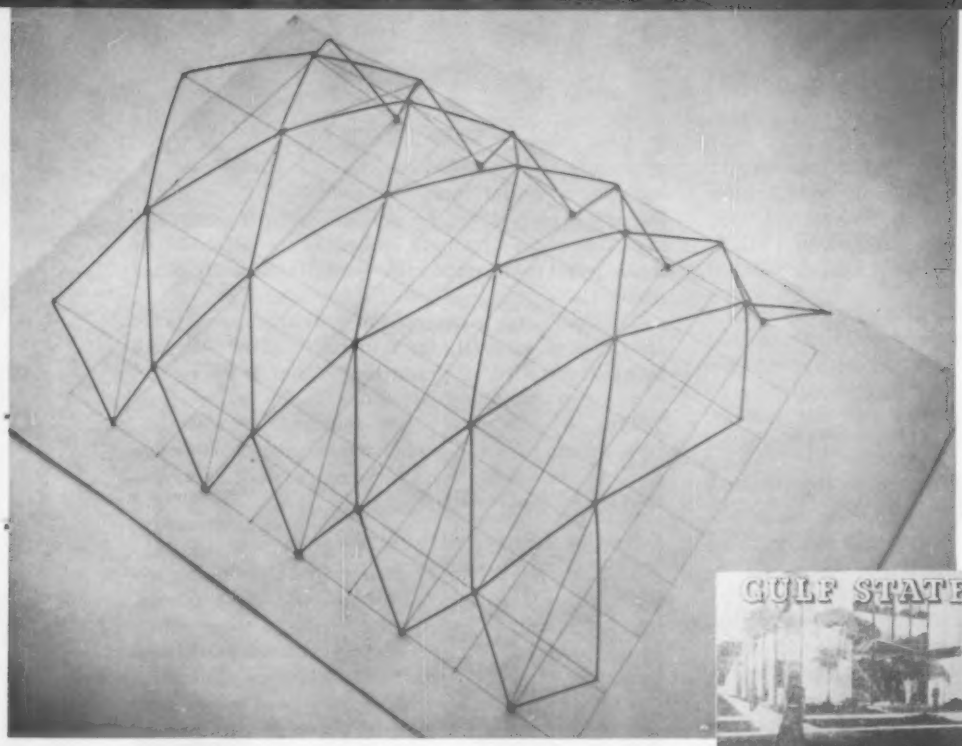
Each hull has four cast armor bump stops inserted into the hull. The joint used is of the complete penetration type and in addition exhibits a welding condition of high restraint. There was considerable concern about this joint during the design stage. A different type of suspension is being considered. If satisfactory, it will eliminate the need of welding the casting into the hull opening, which was found troublesome but overcome by rearranging the application of preheat—Table 4.

Conclusion

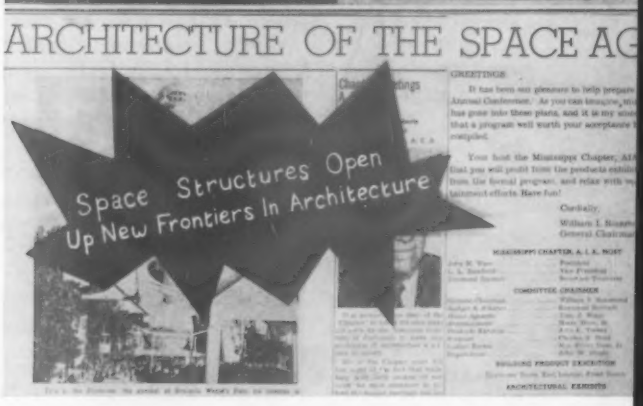
The success achieved in welding the three ferritic hulls demonstrates an outstanding accomplishment. The controls of greatest importance for welding the T95 hulls with the success indicated are as follows:

1. Use of 150° to 200° F preheat.
2. Use of 150° to 225° F interpass temperature. (Once joint was started at preheat temperature, it was completed without allowing temperature to drop below 150° F.)
3. Use of electrodes with maximum moisture of 0.25% for flat position welding.
4. Checking moisture content of electrodes to specification requirements.
5. Maximum 0.30% carbon for cast and rolled armor.
6. Tempering cast armor after flame cutting.
7. Radius weld toes by grinding immediately after welding is completed.

The following inspection methods which contributed to or confirmed the outstanding accomplishment were the examination of all plate and casting edges by dye penetrant prior to welding, grind and dye penetrant examination of backside of root welds, use of dye penetrant examination for each weld pass, and the use of 100% radiography with techniques searching for cracks.



Left—Simple model of rigid frames transformed into a space structure; below—"The Space Age is here; the new architecture is here; steel is here—all ready . . ."



Space structures open up new frontiers in architecture and abstract art is a tool which can be utilized to realize the full potentials of

Creative Architectural Design with Welded

Space Structures

BY MARTIN P. KORN

Unusual expressions of architecture in space are being developed daily—heralding a new creative age. Their effects are visible everywhere throughout the country. Traditional forms of box-shaped buildings have given way to hyperbolic-paraboloid shells, prismatic, fluted and molded shapes, domes and other structures without inner columns—dramatic expressions of movement in space, with emphasis on dynamics.

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Paper to be presented at AWS 42nd Annual Meeting to be held in New York, N. Y., Apr. 17–21, 1961.

These unusual types no longer represent the architects' old precept, "form follows function." Rather do they appear as though inspired by Picasso or Dali—abstract designs in concrete, aluminum and wood, in a surge of creativity without frustrations. Anchored nearby are tapering steel skyscrapers, stalwart, like missiles topped by the sky, seemingly stalled, or waiting inert. Why is steel waiting, in silence, almost sullen?

Steel is still in command of the skies, piercing the heavens at their greatest heights, the number one metal for strength during peace and the only mate-

rial for war's mighty weapons. And if steel should take a notion to reveal new faces in architecture, flex its muscles of hidden strength, go abstract with thrusts in all directions, a sweepstake would result with steel hurtling over the biggest spaces. Welding would add just that magic touch that would assure architectural mastery through its versatility, its ability to make any shape or form, its unlimited application for attaining esthetics, its potential to make possible the impossible—unattainable by other materials.

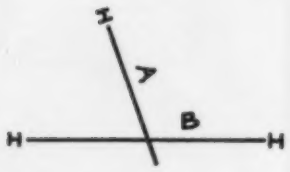


Fig. 1—Simple beam design

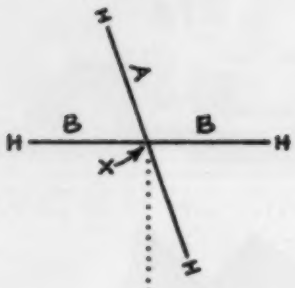


Fig. 2—Continuous beam design

Fig. 3—Introducing height, a third dimension

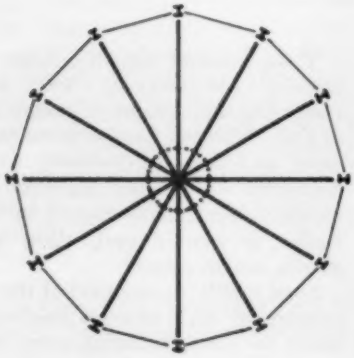


Fig. 4—Domes

The Space Age is here, the new architecture is here, steel is here, all ready for tomorrow—steel designers alone are stalled in yesterday! That is why steel is waiting—simply sad, not sullen.

This paper is an effort to remove that restraint, turn up light on a new tomorrow, meet a challenge that needs only priming to spark and galvanize that state of inertia.

Defining a Space Structure

William E. Dunlap, writing on "Developing the Space-truss Design" in *Engineering News-Record*, May 19, 1960, gives as a definition "a space structure or space frame is a structural framework with members arranged to act simultaneously in three dimensions." That is concise and the article is good reading. Two additional definitions might well be added:

1. A space structure is a three-dimensional continuous framework.
2. A space structure is a multi-planar framework which resists simultaneously in three dimensions all applied forces and/or loads.

Perhaps any or all of the above will make for understanding. But one-sentence definitions do not ordinarily register with most engineers. They do not suffice to convey the structural behavior patterns which set the space structure apart from other types of "lookalike" framing. Since to argue that any structure in space is a space structure is literally but not technically correct, an attempt, is made here to set forth with simplicity and clarity the stress behavior patterns by a series of problems.

Developing the Space Structure

Problem—Simple Beam Design

In Fig. 1, beam A is supported on top flange of beam B and on a column. Beam B is supported on 2 columns. Any load applied to A affects its supporting beam B. But no load on B is transmitted to A.

Problem—Continuous Beam Design

In Fig. 2, beams A and B, in same horizontal plane are supported on 4 columns, rigidly connected at point x of intersection. Any load applied to either beam affects all beams, developing resistance in two directions, similar to that of two-way concrete slabs, or a steel slab supported on 4 columns.

The "diagrid" system of steel framing with beams crossing one another diagonally, rigidly connected at joints, is an extended application of this two-way beam framing.

Problem—Introducing Height, A Third Dimension

Raise point x at intersection of beams in Fig. 2,

Fig. 5—Column details—rigid frames transformed into a space structure (courtesy of Schweizer Stahlbauten, Switzerland)

making intersections rigid and continuous, thus creating the three-dimensional framework in Fig. 3. New stress behavior patterns have now developed, with thrusts induced at columns and tending to overturn them. Ties at tops of columns, or fully rigid connections developing rigid frame action could contain the thrusts.

In three-dimensional framework of this beam and column type, a minimum of three columns is required.

Problem—Domes

Figure 4 represents steel beams arranged as the spokes of a wheel, raised at center, and supported on columns at outer ends, to form a dome (space structure). This type of layout requires a tension ring at the outer ends of beams to take the thrusts. Thrust can also be absorbed through rigid frame action with knees at column tops, a costly operation. For practical connecting purposes, a compression ring is frequently used at the center.

Problem—Rigid Frames Developed into Space Structures

Rigid frames for assembly halls or industrial plants can be transformed into space structures (three-dimensional frameworks) by criss-crossing the rigid frames with rigid connections at intersections and at the columns. The lead photograph shows a model used for teaching purposes only. Figure 5 is a view of the column connections details of this type of welded space structure built in Switzerland. Advantages realized are increased strength of building, tendency toward monolithic stress behavior and decrease in steel tonnage. But such advantages cannot be realized so fully in USA because of the very high labor costs involved for connections.

It should now be easy to understand what makes a space structure. There are, of course, many variations and combinations for the development of three-dimensional frameworks not covered here. A designer with imagination, visualization and intuition will discover that such variations in shape and form are infinite with welding.

Advantages of Space Structures

A space structure serves to enclose the greatest space without inner columns. Space frameworks are also most effective for spanning the largest irregular spaces. Such results are attained with the fullest use of continuity and the most advantageous shapes through welding.

The dome is a type of space structure that offers the greatest possibilities for strength and economy. Prismatic frameworks are equally effective. Steel tops all material for the greatest strength. It can cover the largest area with the least dead load. Welded steel makes possible continuity at every conceivable type of joint and it is a dominant process contributing toward esthetics, unlimited shapes and configurations.

In brief, space structures—especially domes and prismatic frameworks—offer the greatest strength against collapse, against blasts externally and internally.

Truss Type of Space Structure

A space-truss as distinguished from a space structure is a single structural unit or assembly (generally triangular in cross section) which resists applied loads simultaneously in three dimensions. Used for roof construction of buildings as shown in Fig. 6, this type of space structure will function most effectively against dynamic loadings, torsion, uplift and special loadings.

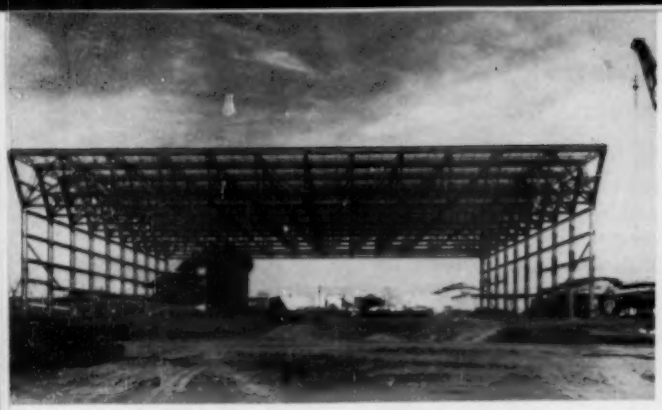
Single space-truss units can be used to good advantage for carrying overhead pipes or conveyors.

Stress Analysis, Philosophy and Intuition

Any complex space structure can be designed in any size of any configuration. The traditional engineering courses in structures, and familiarity with plastic flow and model analysis, are all the science and knowledge required for calculating the stresses.

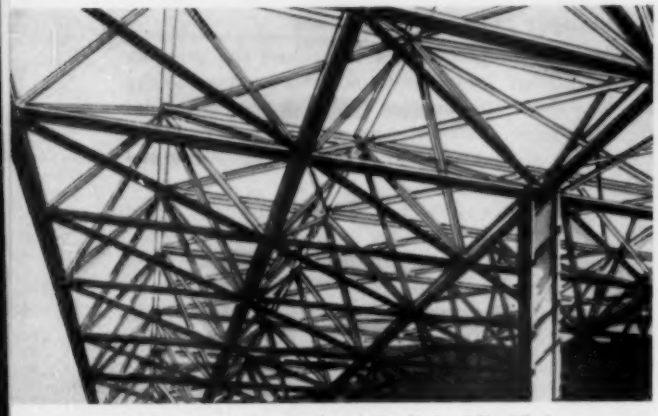
But science is HOW, which includes all mathematics upon which all design procedures are based. None of them contain a WHY—all procedures are regimented mathematics. IBM machines could do better, annihilating time and simultaneous equations.

A new approach is necessary for the design of space structures, one outside the boundaries of science and mathematics attainable only through a philosophy of design, emphasizing visualization, intuition and imagination. Philosophy spells out WHY,



(a) Dallas livestock coliseum (courtesy of Bethlehem Steel)

(b) Multipurpose building (courtesy of Unistrut Corp.)



(c) Truss-space framing (courtesy of Inland Steel Co.)

(d) Open market, Caracas (courtesy of Unistrut Corp.)

Fig. 6—Truss types of space structures:

whereas science spells HOW. And the WHY's should dominate the HOW's before and after design.

The dramatic space structures which are springing up daily are for the most part structural skeletons dressed up in architectural rainment. That new development closes the gap which customarily separates the architect from the engineer. The bigger the open spaces, the smaller the gap, the greater the need for philosophy and intuition in design.

Intuition, a perceptive power, serves effectively for containing failures, for anticipating structural behavior not revealed in computations, for attaining efficacy and economy in your structural skeleton. Its application in design is worthy of consideration by all educators. Hardy Cross, J. B. Wilbur, Pier Nervi and Eduardo Torroja* are among the world's great who accorded it recognition.

One is born with intuition; it cannot be taught. But it can be developed through philosophy. On the strength of this conviction in a recent lecture by the author on philosophy of design at the University of Florida, structural failures were dissected and their causes analyzed—coming up with the WHY's. In the designs of the structures that failed, WHY had not entered into the computations. With the HOW's (computations) found correct, it was apparent that something more than mere computations are needed for safety—that something being the WHY's which furnish the answers and reasons.

The HOW's are in the traditional curriculum, the WHY's are not. The WHY's are more necessary than ever in three-dimensional frameworks, which have their individual behavior characteristics.

Let us meet them alive, not learn from their corpses.

Creative Architectural Design

A noted professor of architecture at Yale once wrote, "The Whitestone Bridge reveals its diagrammatic beauty like a naked Venus." What caused such titillations about its body beautiful? The answer: Slender shafts of compacted strength, touching the heavens with majestic grace, woven strands in lacelike patterns, unified into a song of steel—verily a symphony in sculptured steel.

That bridge is just one example of steel architecture in space, conceived by engineers, acclaimed by architects. Can steel, also, be sculptured for buildings, its natural strength exposed in its naked form?

When the Ninth Annual Convention of the American Institute of Architects, Gulf States Region, convened in 1958, the theme was "Architecture of

* Hardy Cross, before his death in 1959, was professor emeritus of civil engineering, Yale University. J. B. Wilbur, professor of civil engineering at MIT, is co-author of two books on structural engineering. Pier Nervi, partner in the Italian firm of Nervi and Bartoli, has contributed articles to Italian, French, English and American civil engineering journals. Eduardo Torroja is known for his liberal structural designs in Spain.

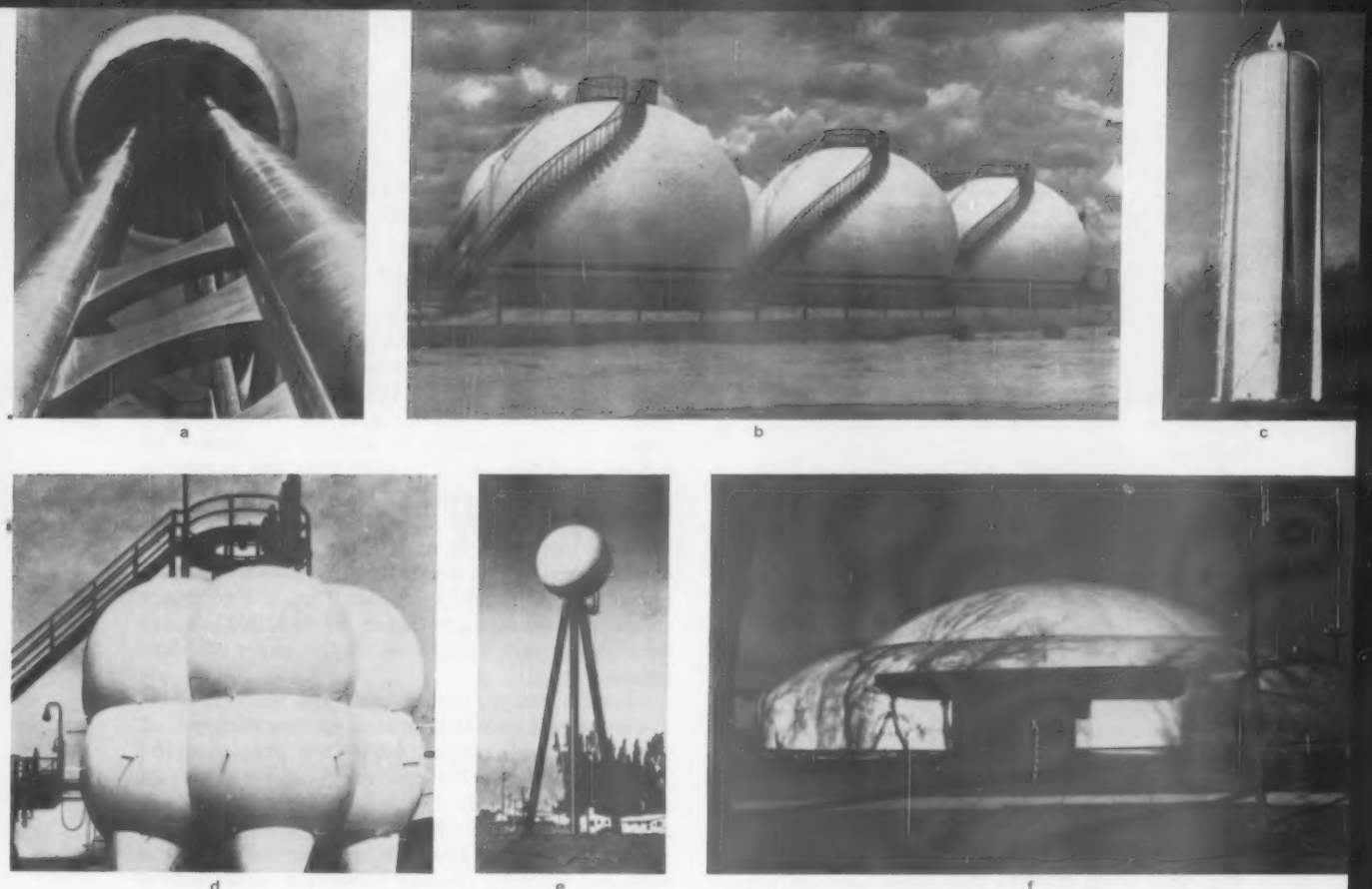


Fig. 7—Sculpture in welded steel (a, b, d, f) (courtesy of Chicago Bridge & Iron Co.)—(c, e) (courtesy of Pittsburgh-Des Moines Steel Co.)

the Space Age"—see lead photograph inset. Creativity was uppermost, and it was a privilege for the author to address this group on space structures. There, again, was strengthened the conviction that one cannot divorce architecture in space from the skeletons of space structures. Those skeletons are products of the engineer's mind, and they make him at once the co-pilot in space with the architect. It is to that co-pilot's mind to which an appeal is now made in an effort to extend guidance into the challenging new worlds which welded space structures offer.

Fabricating plants are numerous around the country and possess the world's greatest experience in structural steel—every facet of plate construction, and the world's best equipment to produce anything; skilled craftsmen and welders everywhere, to fashion new curves for the planets if need be, towering shafts of strength in steel to support them; everything for dreamers to make dreams come true. Dramatic proof is seen in Figs. 7 and 8.

The superabundance of steel, the talent and experience to mold it, surpass all competitive materials for spanning huge spaces. They are as blessings for those who would dream in steel, but the engineer's mind must be attuned to such dreams. Beginning with faith, hope, confidence and cheer, a spirit of gay insouciance to set the moods, a lilt in music to his every step, eyes raised to cerulean skies by day, to galaxies of stars at night, a prayer on each wing of flight into space—such is the mind in which dreams are born!

Dreamland in Welded Steel

If now, by these words, one is lured by a dream, one alights at the doorstep of architects' biggest dream—the New York World's Fair of 1964. What an opportunity, a spot to chant a song of steel—displaying boldly Figs. 7 and 8.

"Here are dreams in steel come true. . . .
Such dreams in steel can build the World's Fair
The steel can be reused, it can be rebuilt,
added to—divided—multiplied—moved! . . ."

A revelation in a lyric not sung before! Perfection? No, just one note missing—steel designers do not always talk the same language as the architect.

The Brussels World's Fair of 1958 had visitors gasping, with abstractions galore. Even the earlier New York World's Fair of 1939 had had some. The 1964 exhibit will have still more of abstract design highlighting its fairyland of architecture.

Most engineers' reactions to abstract paintings are manifested by expressions of disgust. A brief explanation of abstract art may, therefore, prove enlightening. It may, moreover, serve effectively toward widening the breakthrough into creative architecture in steel, already achieved by water tank fabricators and shipbuilders of welded steel hulls.

Abstract art is a form of expression which provides a basic antinaturalistic language of its own for design in architecture, furniture, interior decorating, advertising—in a multitude of things besides painting and sculpture. It is imagery in form and color, the combination of which comes like a jolt, stops one

cold, makes one become all attention and elicits an automatic response.

The imagery may be wild or staid, frightening, whimsical or poetic; the colors exciting or placid, stimulating moods, minds, or just the reverse, provoking atavistic impulses. Even when it contains no object, abstract design definitely leaves an impact on viewers—an impact which may be monstrous in a painting but which is accepted without hesitation in neckties, in posters, textiles, in the decor of homes. Translated thusly into everyday life, it serves architecture also for attainment of dramatic form. Abstract design is here to stay. It is not escapist or a temporary fad fulminating to the tempo of this atomic age.

Looking back, down through the ages, there has always been a close relationship between painting and architecture. Both arts had their baroque periods. Present day interest concentrates on good clean design and the most effective use of materials. But welded steel (incidentally, now the most popular form of sculpture), has hardly been touched for its potential in creative architecture.

Welding has liberated steel from its old limitations to such a great extent that it is now possible to make almost any kind of design. One can experiment with steel as the painters did with paint. The New York World's Fair offers such an opportunity and challenges without parallel in an amalgamation of architecture and sculpture in welded steel. Rhapsodies in welded space structures await all designers there who can free themselves from yesterdays.

"Seek and Ye Shall Find"

In May 1948, THE WELDING JOURNAL published "Creative Architectural Design with Welded Rigid Frames." It contained the notes of a lecture which the author gave at the University of Michigan The considerable public interest manifested helped toward a breakthrough in greater acceptance of welded rigid frames. The deep fears and mysteries about them have since disappeared—everyone is "rigid framing" today with confidence. The space age now here beckons architecture to new frontiers with dynamic three-dimensional frameworks. It is hoped that this effort in behalf of welded space structures will spark as much interest in their understanding and acceptance as the paper on rigid frames.

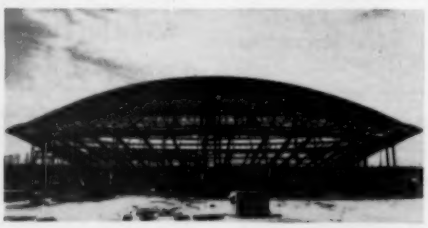
Creative design, now stalled, just waiting, could at once start a mountain of steel moving with welded space structures. Standing by are experts of the American Welding Society, ready to be of service and assistance—with the author on the sidelines, as a volunteer, for guidance on the creative and engineering phases. The welding operator's torch is a symbol, pointing the way to horizons unlimited for creativity of space structures.

"Seek and ye shall find."

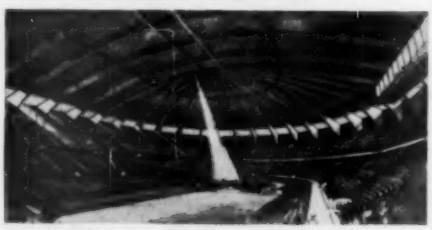
Fig. 8—Dramatic steel space structures

(a) Beth Torah Temple, North Miami Beach, unique three-dimensional framing—(courtesy of D. E. Stevens, AISC)

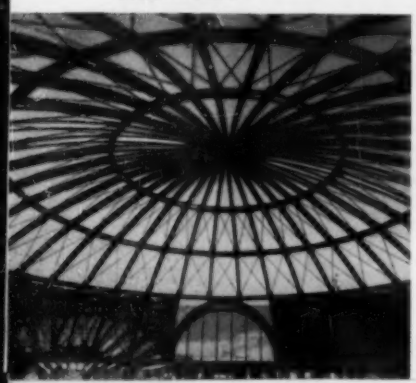
(b) Las Vegas Convention Center



(c) Preliminary design, Detroit Convention Hall, by Martin P. Korn



(d) Greek Orthodox Church, Oakland, Calif.



(e) Gymnasium, Redwood High School (courtesy of Bethlehem Steel Co.)

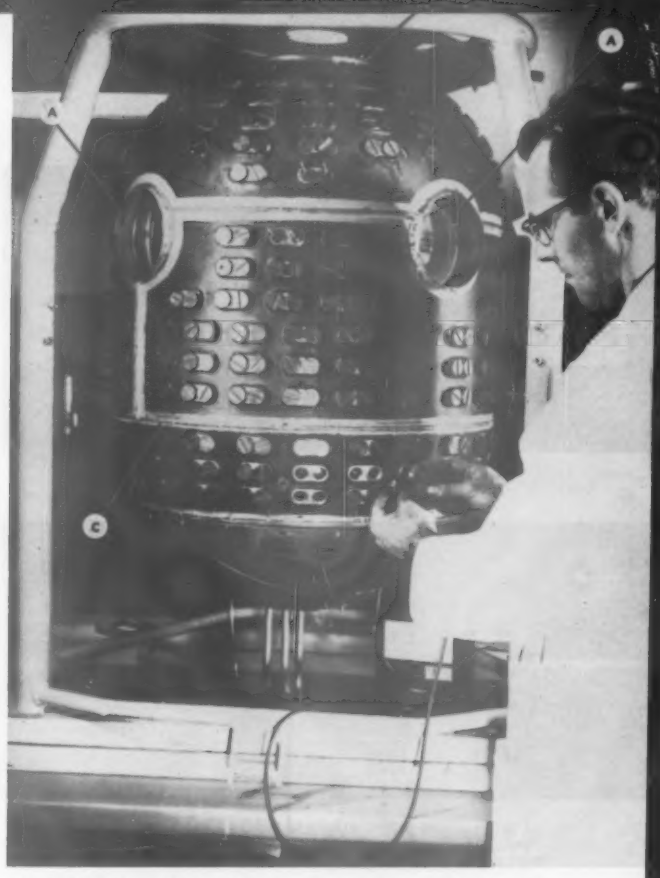
(f) Stainless steel elevated tank (courtesy of Chicago Bridge & Iron Co.)

Ultrasonic Welding

Engineering, Manufacturing and Quality Control Problems

are surveyed together with suggested solutions and related process potentials

BY J. KOZIARSKI



Snap-1A (systems for nuclear auxiliary power). Direct conversion of nuclear energy to electrical energy for space applications

ABSTRACT. Ultrasonic welding is a new process for joining metals that offers unusual opportunities to the designer and manufacturer. It is expected that its main application will be joining dissimilar and refractory metals in spacecraft. In this process there is no melting, cast nugget, significant diffusion, recrystallization, grain growth, grain boundary depletion or formation of brittle intermetallic compounds. Ultrasonic welding may be used for economy purposes or where other joining methods either fail or are impractical. The process provides joint strength that sometimes is considerably greater than that obtained with conventional resistance welding. The consistency of ultrasonic welding is good. In contrast to other welding methods the material degradation is insignificant. However, ultrasonic welding should not be considered as a cure-all. Rather, it will complement other joining processes.

Since ultrasonic welding is a new joining process, based on completely new and not yet sufficiently known principles, it will require a different approach than other processes. The designer must decide whether ultrasonic welding should be used, and so must be educated first. Design allowables, design handbook, manufacturing specifications, welding handbook and quality control criteria will have to be established before ultrasonic welding finds a wider application. More powerful and more flexible equipment is necessary to satisfy present and future needs. Power controls will have to be simplified. Portable equipment is needed. A mechanically attached tip is a must.

Since vibrations in the work may present some serious difficulties, it will be necessary to develop a simple method of checking natural frequencies or standing wave patterns in assemblies or details and to develop some simple means of counteracting them. Changing the inertia moment will probably be the most practical way of reducing vibrations, and damping the next best.

Quality control will also find problems different from those to which it has become accustomed in conventional resistance welding. Practical qualifications for welding equipment and of welding schedules (parameters) will be needed.

Inspection should be simplified because the sectioning of control specimens will probably be unnecessary. It may be expected that X-rays will be of little use, especially in dissimilar metals, because of varying densities and coefficients of absorption. However, these difficulties are not unsurmountable and there are possibilities of monitoring the quality of a weld while it is being made.

J. KOZIARSKI is in Manufacturing Research and Development, The Martin Co., Denver, Colo.

Paper to be presented at AWS 42nd Annual Meeting in New York, N. Y., Apr. 12-21, 1961.

Introduction

Ultrasonic welding has come of age. It is no longer a naive laboratory child, but a grownup individual knocking at the door of modern production. The reception to ultrasonic welding has been mixed. Many have accepted it with enthusiasm as a new and challenging process that makes the previously impossible quite practical. Others have been critical.

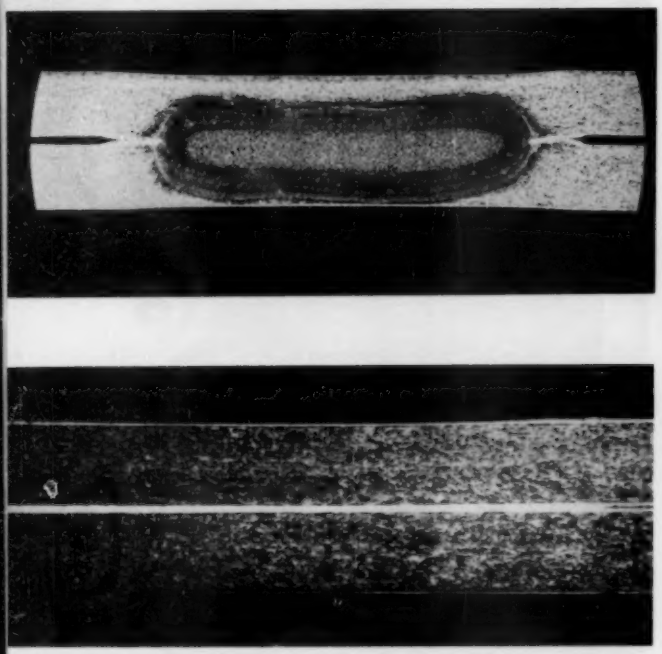


Fig. 1—Photomacrograph of clad 2024-T3 aluminum sheet welded by conventional spotwelding (0.040-in. thick above) and by ultrasonics (0.050-in. thick below)

Fig. 2—Cutaway view of ultrasonic welded snap-1A generator for direct conversion of nuclear energy to electrical energy for space applications (components A, B, and C shown in Fig. 3)

It is possible that the name itself is not representative. In fact, ultrasonic welding is neither necessarily ultrasonic nor welding. The frequency used is from 10 kc up to nearly 100 kc with the heavier equipment working at about 15 kc while the audible limit is 18 kc. Since the audible limit is 18 kc, it is actually sonic. It is not welding, either, by the definition used by the AMERICAN WELDING SOCIETY.[1] Sonic or vibration joining might be a better term.

Ultrasonic welding, which has been under development for only 10 years, has made considerable progress in spite of the fact that only a handful of enthusiasts have been working on it. It is being used in current production, such as joining electrical leads to germanium or silicon transistors, splicing aluminum foil and fabricating atomic fuel elements. In splicing aluminum foil, seam welding at a speed of 400 fpm has been demonstrated.

As a process, ultrasonic welding should not be regarded as a cure-all. It probably will never replace any of the existing welding methods. All will have application without undue competition. However, ultrasonic welding in some cases will either produce better joints or make "impossible" joining practical or even more economical.

Nature of Ultrasonic Welding

Process Characteristics

Ultrasonic welding is a completely new joining process that is unlike older processes. Although the superficial appearance of the joint is similar to conventional resistance welding, this is the only similarity between the two processes. Actually, ultrasonic welding has nothing in common with any of the old or new fusion processes. Friction welding is probably its closest kin.

The mechanism of joining by ultrasonic welding is not completely understood, although recent research provides better understanding.[4] Although the general principle of joint design, manufacture and quality control are valid, the detailed approach to ultrasonic welding should be different from other joining processes. Other welding processes and practices should be forgotten before attempting to use ultrasonic welding. Above all, the old sin of thinking in terms of one process when applying another must not be repeated. This sin is still being committed in fusion or resistance welding when, for instance, a designer applies the old principles used in riveting when conceiving a structure that is to be welded.

Ultrasonic welding has certain advantages. These are principally due, in contrast with conventional or fusion welding, to the fact that no external heat is used. Because of this there is no melting, no cast nugget (Fig. 1) and little or no limitation of spot size, pitch or edge distance. Diffusion and recrystallization are insignificant. Grain growth presents no

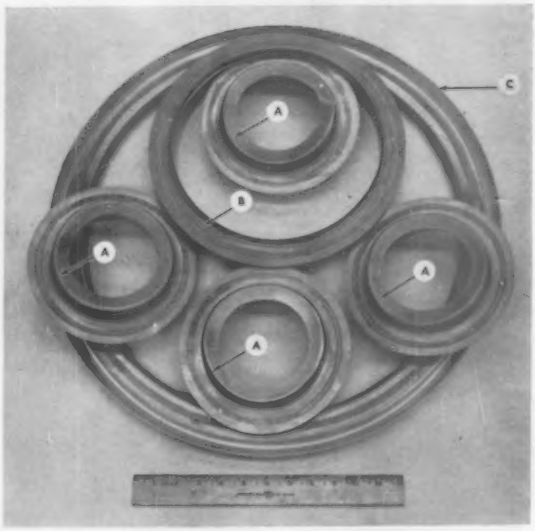


Fig. 3—Set of helium-tight assemblies of stainless steel to aluminum for snap-1A generator made by ultrasonic welding with overlapping spot welds (NOTE: A, B and C refer to the location of assemblies in Fig. 2 and lead photograph)

problem; in fact, sometimes there may be grain refining, as is the case with beryllium. There is no gas absorption and/or porosity formed and the formation of brittle intermetallic compounds is imperceptible. Ultrasonic welding does not impose strict limits on gage thickness. For example 0.0002-in. aluminum foil may be welded to itself or to any thickness of aluminum or other metal.

In spite of these advantages, the acceptance of ultrasonic welding is not as wide as might be expected. On the other hand, the designer needs design criteria, the production man needs production process specifications and production equipment, the quality control group needs quality requirements. All must be reasonably dependable and reliable before ultrasonic welding can fulfill its useful and important role in our activities. The recent edition of the WELDING HANDBOOK[3] contains a wealth of information on ultrasonic welding. However, this is only a good beginning.

Use for Welding Dissimilar Metals

Aluminum may be joined to copper by resistance spot welding. However, such a joint is very weak because of the brittle intermetallic copper aluminite ($CuAl_2$) compound formed at the interface. In contrast, ultrasonic welding produces a sound, ductile joint between these metals. Beryllium, on the other hand, to the best of the writer's knowledge, has so far defied any conventional welding. In contrast, on the basis of limited study, ultrasonic welding appears to offer great promise with this metal.[1]

Stainless steel cannot be joined to aluminum by conventional welding, although these materials can be soldered. By contrast, this is not a particularly difficult problem for ultrasonic welding. As an example, and as illustrated by the lead photograph and Fig. 2, it was necessary to make a number of helium-tight joints for a direct conversion of nuclear energy to electrical energy for space applications (SNAP-1A Systems for Nuclear Auxiliary Power) for space application between 6061-T6 aluminum alloy and AISI 321 stainless steel—Fig. 4.* All conventional joining methods were considered or tried without success. Ultrasonic welding, however, was successful. *In fact, this method saved the entire project.*

Process Economy Potentials

At its present stage of development, ultrasonic welding is quite obviously expensive. However, experience with aircraft and spacecraft shows that a higher cost process or material does not necessarily mean a higher final cost of the product. The following are excellent examples of such economy. It was possible, in one instance, to reduce the cost of one fighter plane by $110,000 because of the use of titanium instead of steel in the first stage compressor of the jet engine. This reduced the weight of the engine by 400 lb and that of the aircraft by 4000 lb (the growth factor† of that particular aircraft was 10). The cost of 1 lb of that aircraft to the government was $40. Simple arithmetic shows that, although the cost of that engine was $50,000 higher than one with a steel first stage compressor, the government saved $110,000 on the over-all cost of a single aircraft.

In missiles, the growth factor may vary from about 5 to 50 depending on the missile and especially on the stage under consideration. A rough study of one particular missile shows that the application of ultrasonic welding to only one system of components would save about 25 lb per the given stage unit. The growth factor for that unit was about 50. Consequently, the over-all potential weight reduction would be 1250 lb per unit if ultrasonic welding were used. It would be difficult to speak, in this case, of the money value of this reduction. However, it would permit either reduction of the weight of the rocket by 1250 lb and thus increase its range or payload after redesign, or it would allow increase of the payload or the range without redesigning but, of course, to a lesser extent.

Engineering Design Problems

The designer and no one else will call for ultrasonic welding on the drawing. The designer *will determine whether ultrasonic welding is applicable.* Consequently, *he must be educated first.*‡ A quick analysis seems to indicate that no designer of reaction-

* The energy converter, incidently was designed to provide 125 w of electric power (28 v, 4.5 amp) or over one million watt-hours of electrical power in one year, the equivalent of 73,000 lb of nickel cadmium batteries.

† Growth factor can be best described by an example rather than a definition. In that particular aircraft the change of 1 lb of the weight of a component produces 10 lb change in the over-all weight of the aircraft in flight readiness. In this case we say that the growth factor is 10.

‡ The following example shows how prejudicial opinion may be harmful. One of the prominent professors of a famous school of aeronautics used to say: "Welding cannot be used for any critical part of an air-

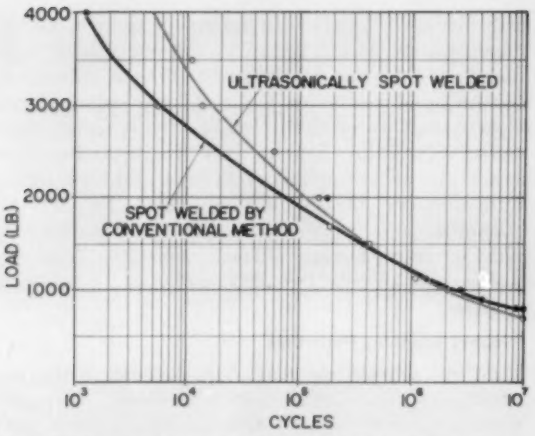


Fig. 4—S-N curves for clad 0.050-in. 2024-T3 aluminum alloy sheets spot welded ultrasonically and by conventional method. R = 1.4

propelled craft, particularly spacecraft, can ignore ultrasonic welding.

Joining dissimilar metals or alloys, without embrittlement and with unusually high strength, will probably be the most challenging possibility in spacecraft design. Joining refractory metals and joining ceramics and plastics to themselves or to other materials by ultrasonic welding is another possibility. All this is possible with little or no strength degradation, even in alloys that have been heat treated or cold worked. (*Degradation* is the decrease of strength of the base metal due to welding. It is expressed in percentage. This is the basis for the establishment of the efficiency factor.[5])

Ultrasonic welding may also find application in joining such materials as sintered aluminum powder (SAP) and dispersion hardened or other sintered alloys. The joining of metals with such widely spread melting temperatures as tungsten and aluminum should not be overlooked. On the other hand, the designer may be interested in getting as much as 900 lb of tensile-shear strength from a single spot weld joint on bare 0.040-in., 2024-T3 aluminum alloy sheet or as much as 1300 lb or even more than 1600 lb (if heavy surface scuffing is not objectionable) with clad, 0.040-in., 2014-T3 alloy. For comparison, it may be interesting that MIL-W-6858A requires only 345 lb minimum and 435 lb minimum average for the same gage of both clad and bare sheets. A designer of electronic equipment may find that, in addition to joining transistors to transistors leads, without objectionable heat, it is possible to get a joint (e.g., on a printed circuit board) that will be good to the melting point of the lead and a joint between gold-plated Kovar wire and nickel bus bar that will consistently be stronger than the base wire itself.

frame or engine because it is unreliable and because it cannot be controlled." This was in 1929, although in 1916 swarms of Fokker fighters were in the air during World War I and in 1926 Lindbergh had flown his *Spirit of Saint Louis* across the Atlantic. Both aircraft had welded tubular steel fuselages.

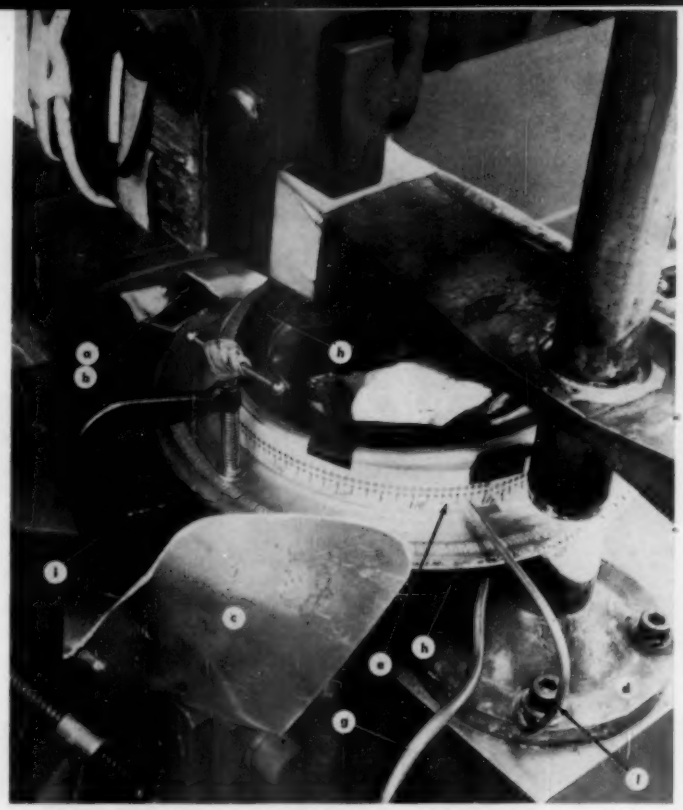


Fig. 5—Assembly A (Figs. 1, 2, and 3) in a fixture on the 4000 watt (reducing vibrations by damping): a —table, vertical location; b—prevention of assembly against tilting; c and d—location in horizontal position; e—index; f—index finger; g—cooling air jet; h—damping polyvinyl chloride tape; i—"C" clamp for handling only

Designers also should know that ultrasonic welding, unlike conventional spot welding, in order to suit practical design requirements permits altering to some extent the strength of a joint by changing spot size, spot spacing and even by changing the direction of vibrations during welding. Although preliminary tests show that fatigue properties of an ultrasonically welded joint are similar or slightly superior to those made by conventional spot welding, (Fig. 5), it may be expected that specially designed joints to suit ultrasonic welding might show still better results. This would be because of possible lower residual stresses, and because there are indications that the ductility and peel strength of a weld made ultrasonically are higher than those made by conventional spot welding.

The first questions the designer will ask concerning ultrasonic welding are what can be joined, how are they joined, what will be the joint configuration, and depending on the environment, what precautions must be taken to assure reliable design. All this information should be included in design manuals such as *Handbook of Instructions for Aircraft Designers* for the Air Force or *SD-24* for the Navy. How much strength may be expected from an ultrasonic weld on a given material will be the next question that a designer or a stressman will ask. This data should be contained in a publication such as MIL-HDBK-5, *Strength of Metal Aircraft Elements*.[5]

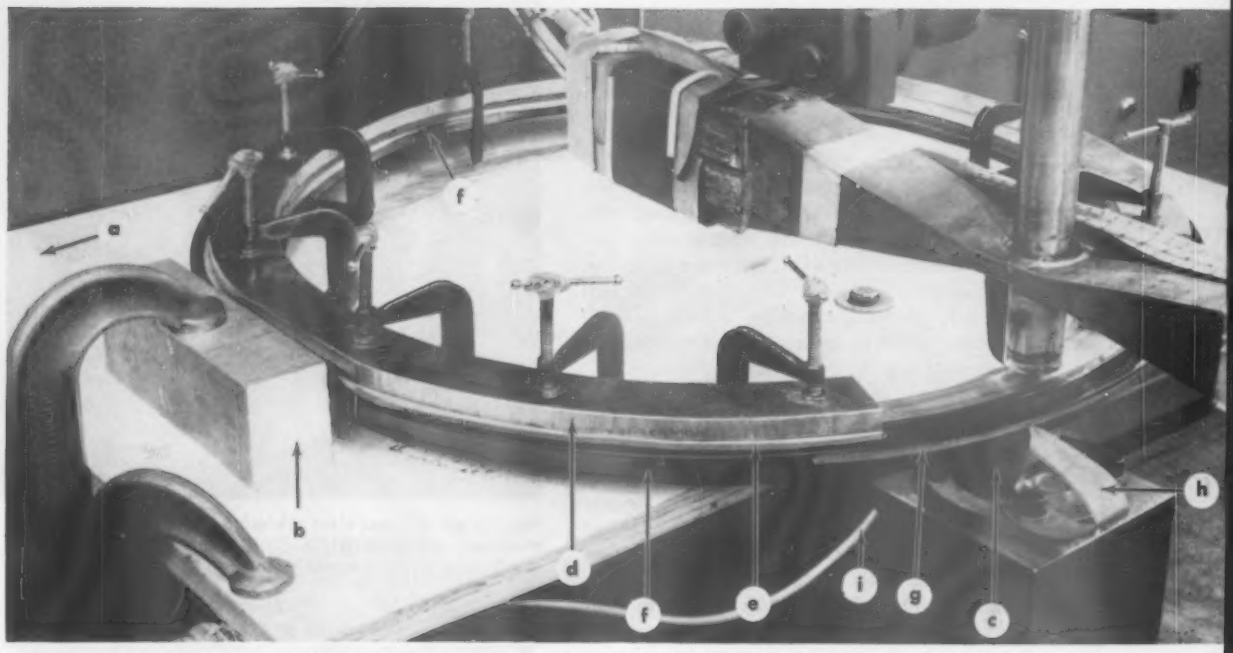


Fig. 6—Assembly C (Figs. 1, 2 and 3) in a fixture on the 4000-w unit (reducing vibrations by damping and by changing the inertia moment of the assembly with clamping rings): a—table, vertical location; b and c—location in horizontal position; d—$^3/_8$-in. aluminum clamping ring; e—rubber damping plate; f—polyvinyl chloride damping tape; g—index; h—index finger; i—cooling air jet

Manufacturing Problems

Power

More power will be necessary. Presently available units are capable of joining the approximate maximum thicknesses of different metals and alloys listed in Table 1.[7]

Lack of adequate power is a rather serious limitation, especially if higher strength or refractory metals are concerned. It seems that hardness, yield strength, modulus of elasticity and ductility are the main controlling factors that limit maximum possible thickness that can be welded. More powerful equipment is necessary to overcome these limitations. For instance, preliminary tests showed that 0.020-in. thick beryllium could be welded if more powerful equipment were available.[7]

Portability

Ultrasonic welding would be a very valuable means of production (e.g., for attaching slips, thermocouples, etc.) if powerful enough portable equipment were available. In the case of ultrasonic welding, the power source can be hundreds of feet from the welder; it has been reported that such a welder has already been made for experimental purposes and that it may soon be available.[7]

Table 1—Maximum Sheet Thickness That Can be Welded to Itself by Presently Available Ultrasonic Equipment

Alloy	Thickness, in.[a]
1100 aluminum	0.100
2024-T3 aluminum alloy	0.064
Unalloyed molybdenum	0.025
Tungsten	0.010
Tantalum	0.030
Austenitic stainless steel	0.035

[a] Refers only to the thinnest detail on the sonotrode side; there is practically no limitation on the thickness of the detail part that is on the anvil side.

Cooling

New 4000-w welders are supplied with water-cooled sonotrodes. This considerably improves the performance of the welder because the tip is kept cool. Before this improvement, with the uncooled sonotrode, the side (not the contact area) of the sonotrode tip reached about 300° F. after a few spotwelds. Of course, the temperature of the contact area of the top, itself, would be much higher. By contrast, the cooled tip is always completely cold. However, it was found that tap water should not be used for cooling, especially if its pH is low (acid), because it will attack the sonotrode in the area of the braze since the braze filler metal is cathodic to steel. Therefore, an integral cooling system with the output of about 5 gal/hr and 18–20 lb sq in. pressure was installed. The use of distilled water inhibited with 0.5% of sodium chromate (Na_2CrO_4) has been found to be satisfactory. The installation of flexible air jets for cooling the welded assembly during welding would also be advisable—Figs. 5 and 6.

Clamping Force

Better control of the clamping force at the low end will be advisable. This could be obtained

by the installation of back-pressure valves in the pressure system and two pressure gages—one for high, another for low pressure.

Tips

Tips, in particular the sonotrode tip, at present are the most pressing problems. Tips are attached by silver brazing at present. This is a delicate and messy operation if performed by hand. The sonotrode-coupling joint, which also is brazed, and the transducer cables have to be protected against heat with wet rags. The quality of the joint is never certain. Thus a mechanically attacked sonotrode tip, which will efficiently transmit the power but will not gall, is a *very pressing necessity*. Work on such tips is reportedly now in progress, and results are said to be promising.

Figure 7 shows the contact area of a water-cooled sonotrode tip made from hardened tool steel (Rc-62). It shows a system of cracks and areas from which the material has been chipped off. Although it has been found that slight cracking itself is not detrimental to weld quality, it is a question whether the cracking should not be removed by dressing before it develops into deep cracks. However, it was found that first chips and/or erratic tensile-shear results on the control specimens indicate that the tip should be changed. The crack system always has a special pattern that follows the stress distribution. However, it seems to have a tendency to follow the direction of the grain flow. The life of a tip is unpredictable. The tip shown in Fig. 8 made about 4700 overlapping spotwelds, with a speed of 8 to 20 spots/min. Although this was a very good performance, other tips failed after a smaller number of welds although used with the same power level, about 1700 w. At present hardened tool steel or age-hardened high-nickel alloy are used to fabricate tips.

Although excessive tip sticking is harmful, some light tip sticking is an indication of a good weld. In fact, to some extent, an experienced operator can judge the quality of a weld by the amount of tip sticking and the sound. This tip sticking has to be released abruptly and immediately after the weld has been made. The end of the power delay and before the clamping pressure is reduced to zero is the optimum moment to start releasing the weld. This operation is done manually today. This presents two disadvantages:

1. It is difficult to catch up the exact moment to release (by turning) the assembly.
2. It is tiring and may even be impossible to the operator, especially when large assemblies are being welded.

Some mechanical means, timed with the welding cycle, must be devised to release the weld. A noncontinuous, roller spot welder, instead of a spot welder, may be the answer in some cases. This would have another advantage because each weld would be made by a different area of the rollers which might reduce cracking.

Fig. 7—Face of a tool steel sonotrode tip showing fatigue cracks and chipping (NOTE: This tip made about 4700 overlapping spotwelds with a speed of 8 to 22 spots/min)

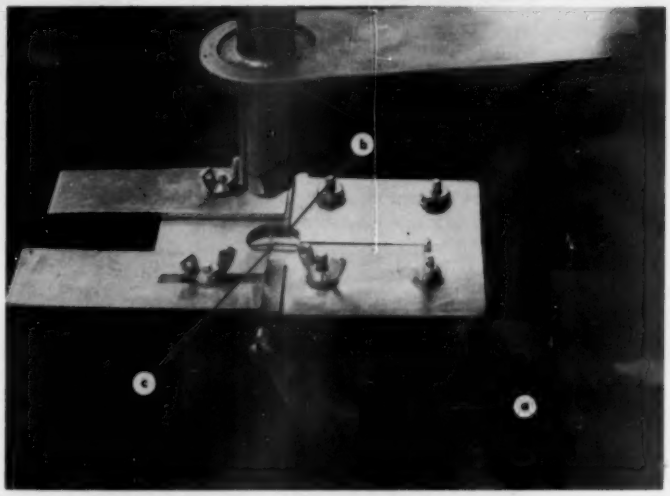
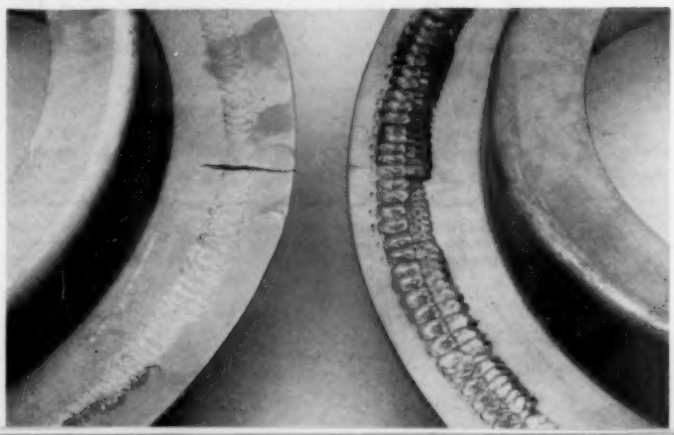


Fig. 8—Small fixture attached to 600 w unit anvil for small electronic assemblies (a—anvil; b—anvil tip; c—welded assembly)

Fig. 9—Cracks on stainless steel during repair—longitudinal vibrations of the sonotrode



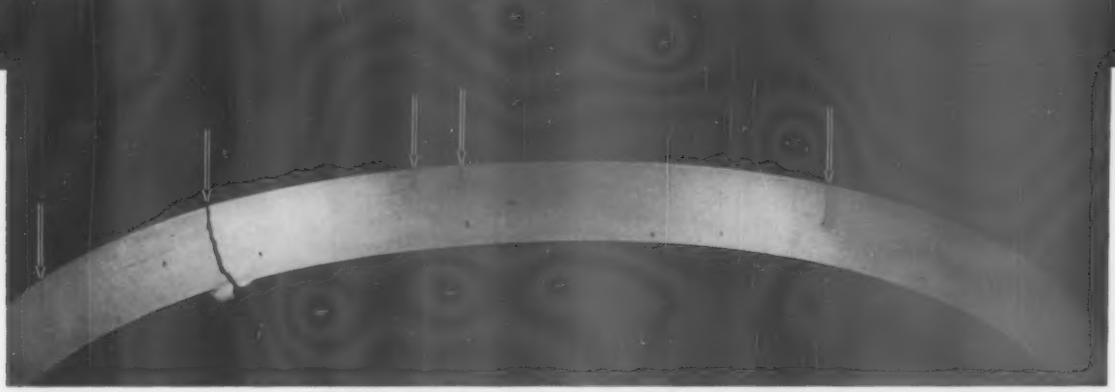


Fig. 10A—Cracks on flanges normal to welded flat areas—(Note: Arrows show cracks and see discoloration around crack on stainless steel flange)

(a) 6061-T6 Aluminum flange

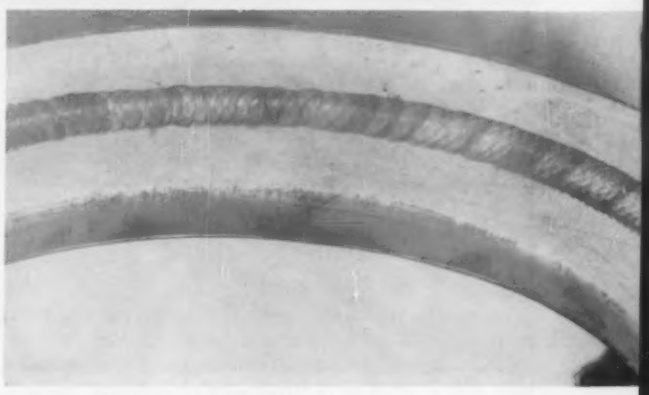


Fig. 10B—Enlarged view from Fig. 10A

(b) 321 stainless steel flange

Positioning Fixtures

In Figs. 5 and 6, positioning fixtures for relatively larger assemblies are shown and in Fig. 9 for very small assemblies. It should be noted that, in each case, the anvil has been used either as one of positioning means (Figs. 5 and 6) or as a base to which the fixture is attached (Fig. 8).

Vibration

There is little experience concerning the effect of vibration of the joined assembly on ultrasonic welding. However, there appear to be only a very few cases when vibration produced some minor difficulties.

It has to be expected that the vibration of the sonotrode during welding induces some vibration in the welded assembly. These vibrations might, in extreme cases, be resonant if the natural frequency of the assembly is the same as the frequency of the sonotrode, or might be induced if there was no resonance. In the former case, little force will be necessary to produce considerable deflections of the assembly or of the details. In both cases, however, some energy loss in producing a weld should be expected.

Turning now to actual examples, no good joints resulted when attempts were made to weld assembly A in Fig. 3 for the SNAP-1A project with vibrations of the sonotrode longitudinal to the weld, although a completely enclosed assembly made previously as a feasibility study was successful. Results were: no joints, very poor joints or leaking welds. This assembly was made from two details (both 0.031-in. sheet and formed with a Martin Co. patented process). One detail was made from 6061-T6 aluminum alloy and another from AISI-321 stainless steel. Rewelding the leaking areas produced cracks in the stainless steel flange—Fig. 9. Cumulative extrusion of the 6061-T6 detail was observed. This was thought to induce high shear stresses along the interface of the weld, mechanically weakening or even breaking the weld.

Subsequently, vibrations were changed to normal to the weld. Good welds were made; but this time, almost equally spaced cracks were formed in the 6061-T6 alloy flange which was at a right angle to the flat on which welds were made—Fig. 10A. Standing waves were probably responsible for cracking.

A careful deburring of the edge and an application of a 0.01-in. polyvinyl chloride tape to that flange stopped cracking; but the stainless steel flange, also at a right angle to the welded flat, cracked—Figs. 10B and 11. Only one crack resulted with considerable discoloration indicating heavy heating. Obviously both flanges were vibrating as rings. The tape on the 6061-T6 flange disintegrated at almost regular intervals around the circumference during that test—Fig. 11. This showed how much energy was absorbed by the tape by damping.

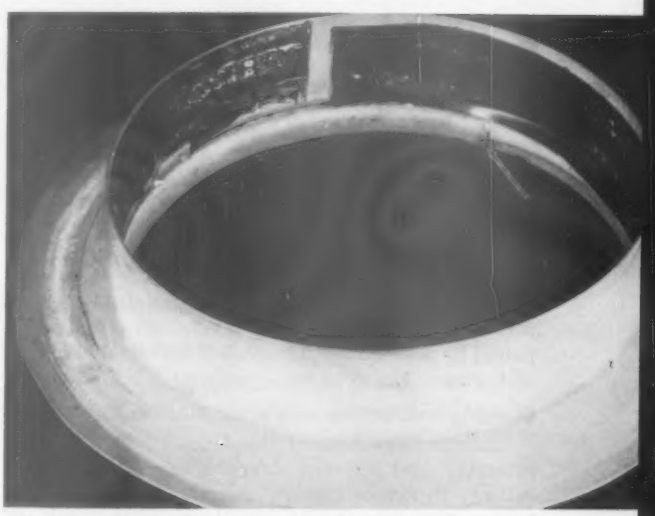


Fig. 11—Disintegrated tape used for damping vibrations (tip vibrations normal to the weld) on 6061-T6 flange—arrow indicates crack on the stainless steel flange

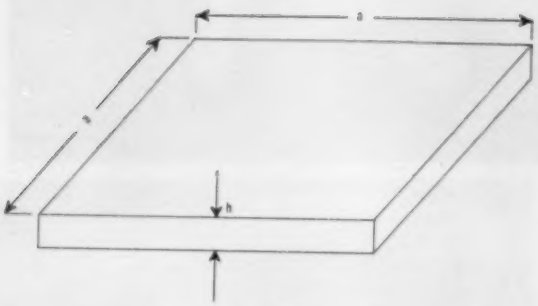


Fig. 12—Vibrating square plate with free edges and made from perfectly elastic, homogenous, isotropic material

Control of Vibration

Damping

Damping is the first resort in reducing vibration amplitudes. This measure was applied to assembly A in Fig. 3. A 0.010-in. polyvinyl chloride tape was applied to both sides of each flange (normal to welded surfaces—h in Fig. 5). This was successful but uneconomical. Damping consumes energy—Fig. 11. Consequently, either less energy must be used for making the joint or the loss has to be made up by increasing the welding power (compared to that needed for test specimens) during the establishment of welding parameters. The power increase had to be established by experience during actual welding by controlling the intensity of sticking and to some extent by the sound.

Although damping was successful in making assembly A in Fig. 3, it was only marginal in assembly B shown in Fig. 3 and completely inefficient in assembly C. Although no assembly showed any cracks or tape disintegration, assembly B showed small leaks during testing with air under 30 psi of pressure. Those leaks, however, were easily repaired by rewelding. Assembly C defied any amount of taping. No weld was possible.

Changing Natural Frequency of the Detail or Assembly

Changing the natural frequency of the detail or assembly (and standing waves) is the most economical way to reduce harmful vibrations to a practical level. A simplified test case is a square plate with free edges consisting of perfectly elastic, homogenous isotropic material, with the dimensions shown in Fig. 12. According to Timoshenko[5] the natural frequency of such a plate would be.

$$f, \text{cps} = \frac{\alpha}{2\pi a^2}\sqrt{\frac{D}{\rho h}} \qquad (1)$$

with, D = E I

$$f, cps = \frac{\alpha}{2\pi a^2}\sqrt{\frac{EI}{\rho h}} \qquad (2)$$

$$I = \frac{h^3}{12(1 - \mu^2)} \qquad (3)$$

consequently

$$f, cps = \frac{\alpha h}{2\pi a^2}\sqrt{\frac{E}{12\rho(1 - \mu 2)}} \qquad (4)$$

where

α = { 14.10 for the first order. 20.56 for the second order. 23.91 for the third order.
a = length of the side of the plate.
h = thickness of the plate.
E = Young's modulus of elasticity.
I = inertia moment.
ρ = mass density.
μ = Poisson's ratio.

Changing the length of the side of the plate, a, would be the most economical way of affecting its frequency. Changing the plate thickness is the second most economical way—provided the other parameters remain constant (formula 4 above). This is illustrated by Fig. 13 which shows specimens made from 0.031-in. 6061-T6 aluminum alloy sheet (upper row) ultrasonically welded to 0.031-in. AISI 321 stainless steel (bottom row). Longitudinal (parallel to the longer side) vibrations of the sonotrode were used. No problem was experienced in welding 0.75 x 2.5 in. (A and B) specimens. However, welds with 1- x 4-in. specimens were very erratic: very low strength (C); high strength (with the 6061-T6 nugget pulled out during tensile-shear testing) (D); no weld at all and a heavy discoloration of the 321 stainless steel strip (E), indicating high-energy dissipation in the form of heat. Welds were perfect when strips of dimensions C were sectioned into two (G and H). Also, clamping the 1- x 4-in. specimen between two heavy plates was efficient in producing a good weld (F in Fig. 13); however, changing the physical dimensions of the actual detail would be impractical in most cases.

Although formulas 1 to 4 are valid only for that edge-free plate, they may indicate what can happen to other configurations (e.g., to plates with flanges) because the parameter locations in the formulas will be nearly the same. With flanged edges, the total inertia moment will be more efficient than the plate thickness. Adding clamping plates as in Fig. 14 or clamps alone will affect the inertia moment and, of course, the natural frequency of the assembly. However, the effect of mass density is opposite to that of the inertia moment. Although changing the frequency of the assembly alone would be the most economical, sometimes decreasing vibration intensities may be obtained by a combination of damping and changing the inertia moment of the assembly—Fig. 6. In this case, heavy $^3/_8$-in. aluminum rings, d, were used on both sides to change the inertia moment; polyvinyl tape was taped on both sides of both flanges, f; and a rubber plate, e, was inserted between aluminum rings and welded surfaces. The last two were used as dampers.

Changing Direction of Sonotrode Vibrations

In some cases, changing the direction of sonotrode vibration may be efficient to some extent to improve joint quality. Although any consistent weld could not be made with unclamped specimens C, D and E when longitudinal vibrations were used, transverse vibrations were more successful. However, chang-

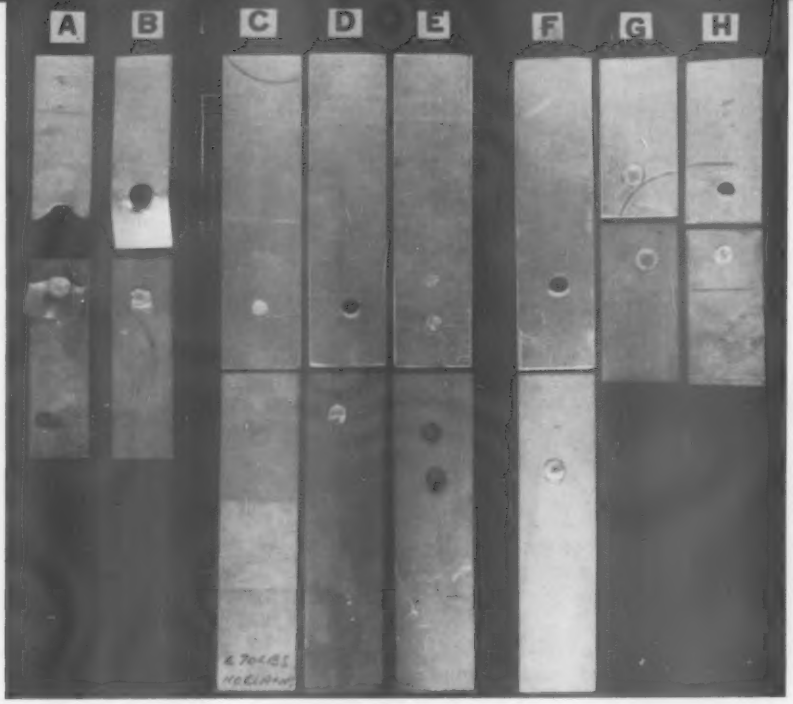


Fig. 13—The effect of size of the specimen on weld quality.

Upper row—6061-T6 aluminum sheet
Lower row—AISI 321 stainless steel sheet
A & B—0.75 x 2.5-in. specimens—good welds; C, D & E—1 x 4-in. specimens—erratic results; C—low strength (70 lb) weld; D—good weld E—no weld; F—clamped specmens (good weld); G & H—Specimen C sectioned into two before welding (good welds)

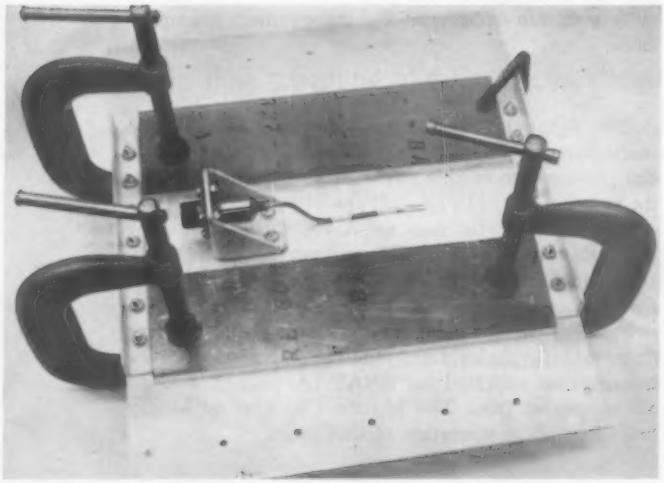


Fig. 14—Changing frequency of a plate by changing its inertia moment (clamping)

ing the direction of vibrations may produce other difficulties—Figs. 10 and 11.

Future Action

It is difficult to say what action should be taken on vibrations now. The trial-and-error method is not always efficient or economical. More investigation is needed on vibration problems in three areas:

1. Exploration of the wave systems in different types and shapes of assemblies and their effect on loads and stresses;
2. Establishment (if possible) of a simple, practical method of checking the vibratory wave systems on the actual detail parts or assemblies;
3. Establishment of general rules on how these vibrations can either be made harmless or, at least, be brought to an acceptable level.

Automation is very important in present technology for economy and elimination of human error. A theoretical analysis indicates that automatic fabrication in ultrasonic welding will be easier than that in conventional resistance welding.

A general process specification will be necessary. It should contain: general preparation of details, selection of welding equipment, establishment of welding parameters (schedules) and special precautions. It could serve as the basis for the preparation of detail process specifications. A welding manual will be another "must"; it should include a description of the equipment, its operation and maintenance and trouble-shooting.

Welding Schedules (Parameters)

Quality Control Problems

Ultrasonic welding has three parameters to be established and controlled: pressure (clamping force), power and time. Even these may vary within some limits without affecting weld quality. In contrast, there are six parameters in resistance welding: current, time, squeeze pressure, weld pressure, preheat and postheat. All are critical. Only small deviations are permitted from welding schedules. A modern resistance welder may have as many as 25 different control knobs and switches. On the other hand, an ultrasonic production welding unit has about eight control knobs and switches. Controls should be simplified even further on future equipment.

Welding schedules (parameters) would be simpler than for conventional spot welding or seam welding because the ratio of welded sections is not critical. In welding similar metals only thickness on the sonotrode side will have to be taken into account. This may be somewhat more complex with dissimilar metals.

Cleaning

Very critical cleaning and deoxidizing of aluminum and aluminum alloys as called for in conventional resistance welding is not necessary. However, surfaces to be welded must be positively degreased. Otherwise, either higher than necessary energy would have to be used or erratic welds will result. The surface oxide is usually not objectionable, although its removal produces better consistency. In fact, good welds can be made through artificially oxidized surfaces or even through some coatings.[7]

Quality of Detail Parts

The quality of detail parts, especially of those cold-formed from sheets, should be at least as good as for resistance welding. The surface should be free of wrinkles or pits—especially for gas-tight joints.

Edge preparation is also critical. Edges should be smoothly deburred in the longitudinal direction. Any scratches normal to the edge will potentially start cracks. The fit should be very good because tip pressure (although not very critical) is relatively low in ultrasonic welding.

Qualification of Welding Unit

Welding unit qualifications are expected to be simpler than for resistance welding machines. The power source and the welding unit will have to be qualified separately. However, no qualification needed for the electric power supply will be as critical as the qualifications for resistance welding units.

Inspection

Similar to resistance welding, control specimens made in certain period of time will also be necessary. However, only visual observation and tensile shear will be required. Sectioning for macro will not probably be necessary because there would be no such defects as porosity, cracks, spitting, burning and sheet separation, which are common defects in conventional resistance welding.

It will probably be possible to make continuous inspection of ultrasonic welding by means of the observation of standing wave ratios on a simplified oscilloscope or by recording by oscillograph.[7] A continuous permanent inspection record could thus be secured. The work being done in this field by Aeroprojects, Inc., seems to be very promising.

Visual inspection of an ultrasonic weld may be very important. The size, geometry and general condition of an impression may be a good indication of the quality of the weld. For instance, the discoloration of the stainless steel weld indicates energy dispersion which is transformed into heat.

It is doubtful whether X-ray inspection will have an important role in inspection of ultrasonic welding. It might possibly have application in checking the size of the nugget. Difference in densities and difference in coefficient of absorption will make X-ray usefulness very doubtful when dissimilar metals are joined.

Penetrant inspection will probably be useful in checking for surface cracks.

Conclusion

Ultrasonic welding is a "must" for the design and manufacture of space craft. Design criteria, manufacturing specifications, and handbook and quality control requirements must be established.

Ultrasonic welding presents many unknown fundamental problems that will have to be solved before any further progress may be expected. Dynamics, acoustics, thermodynamics, solid state physics, chemistry and metallurgy will be used to find necessary answers. This research work should be done quickly. It seems that to obtain the fastest possible results this research should be either an aircraft and space industry cooperative program or a program sponsored by government organizations.

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References

1. WELDING HANDBOOK, Fourth Edition, Section One, *Standard Welding Terms*, AMERICAN WELDING SOCIETY, 1.21, 1957.
2. Jones, J., Byron, and McKaig, Harold, L., *Ultrasonic Welding and Improved Structural Efficiency*. IAS paper No. 60-10 presented at the Institute of the Aeronautical Sciences Annual Meeting. New York, N. Y., Jan. 25–27, 1960.
3. WELDING HANDBOOK, Fourth Edition, Section Three, Chapter 52, *Ultrasonic Welding*, AMERICAN WELDING SOCIETY, 52.1 to 52.36, 1960.
4. Jones, J. B., Maropis, N., Thomas, J. G., and Bancroft, D., *Fundamentals of Ultrasonic Welding, Phase I*. Report No. FR-N-294, Aeroprojects Inc., Navy Contract No. NOas 58-108-C (May 1959).
5. MIL-HDBK-5, *Strength of Metal Aircraft Elements*, Armed Forces Supply Support Center (March 1959).
6. Koziarski, J., "Some Considerations on Design for Fatigue in Welded Aircraft Structures," THE WELDING JOURNAL, **38** (6), 565–575 (1959).
7. Data and information by the courtesy of Aeroprojects, Inc.
8. Timoshenko, S., Vibration Problems in Engineering. D. Van Nostrand Co., Inc., Toronto, N. Y., London (1955).
9. Neare, N. E., Antonevich, J. N., and Monroe, R. E., "*Fundamental Studies of Ultrasonic Welding*," THE WELDING JOURNAL, **39** (8) Research Suppl., 331-s to 341-s (1960).

Over-all view of fabricating shop showing peripheral sections in foreground and internal sections toward the rear

Tight time schedules and rigid quality requirements are met when using the submerged-arc and covered-electrode processes for the

Welding of Massive **Manganese-Vanadium Steel** Assemblies for Verrazano-Narrows Bridge Tower Piers

BY IRVING DIAMOND

Fabricating the huge caisson cutting edges for the two tower piers of the Verrazano-Narrows Bridge has presented a challenge. In the first place, the time schedule was tight. In the second place, quality requirements were exceedingly high. These were further complicated by the fact that ASTM 242 low-alloy high-strength manganese-vanadium steel plate in $^1/_2$, $^3/_4$ and 1-in. thicknesses were involved.

In addition, each of the two units was composed of 28 subassemblies, varying in length from 33 to 60 ft, 5 ft wide and 7 ft high. These pieces had to be welded into units which would fit at installation within a $^1/_{16}$-in. tolerance. Total weight of the sections in each of the two cutting edges was close to one million pounds; total length of welds for both cutting edges is 65,000 ft or approximately 11 statute miles; total weight of filler metal for both cutting edges is $13^1/_2$ tons.

IRVING DIAMOND is Vice President, Elizabeth Iron Works, Union, N. J.

In order to understand the magnitude of the job and the nature of the problem, some of the specifics with respect to the material, the design and the assembly should be reviewed.

The Material

Specifications called for manganese-vanadium low-alloy high-strength steel, meeting specification ASTM-A242, and conforming to the following percentage (%) chemical analysis.

Carbon	– 0.22 max
Manganese	– 1.25 max
Phosphorus	– 0.04 max
Sulfur	– 0.05 max
Silicon	– 0.30 max
Copper	– 0.20 min
Vanadium	– 0.02 min

Low-alloy steel of the above analysis was specified for this job because of its higher strength and weldable characteristics and because the use of this steel also reduces reinforcing rod requirements in the concrete within the cutting-edge region of the

caisson where the space available is tight, thus resulting in a superior concrete job. Thicknesses of $^1/_2$, $^3/_4$ and 1-in. hot-rolled plate were used in conjunction with structural rolled angles. To facilitate operations most of the plates were preformed, prebent and precut.

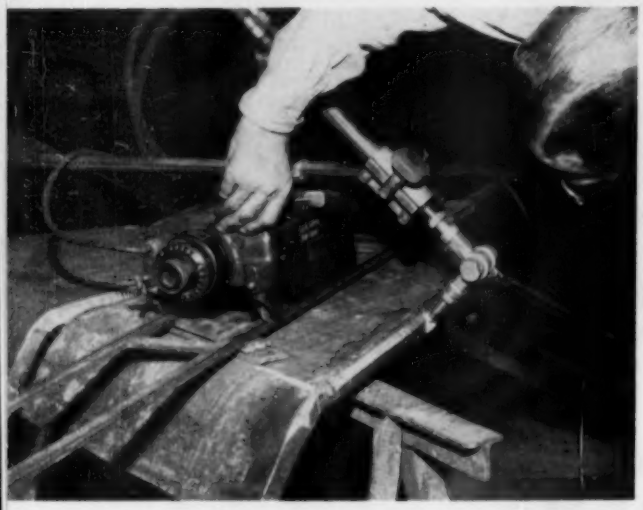


Fig. 1—Edges of manganese-vanadium steel plates are beveled with radiagraph

The Assembly

The caisson cutting edge consists of a series of peripheral sections joined by internal cross sections. The full rectangular assembly covers close to 30,000 sq ft. These cutting edges will armor the bottom of the two tower piers. By a combination of weight and carefully controlled excavation procedures, the caissons will be sunk to a depth of approximately 127 ft below sea level for the Staten Island Tower Pier and 197 ft below sea level for the Brooklyn Tower Pier.

Preparing the Plates

When the plates are received from the mill, they are stored horizontally and separated by wood grillage members. This permits fast individual handling. As the plates are needed at assembly, they are laid out for oxygen cutting with natural gas for preheat. All edges are beveled using radiagraphs—Fig. 1. Specifications require that the beveled surface be smooth and have no objectionable grooves or gouge marks. Plate-edge bevelling is carried out with oxygen cutting on $^1/_2$-in. thick plate at 10 ipm, on $^3/_4$-in. plate at 8 to 7 ipm, and on 1-in. thick plate at 6 ipm.

Peripheral Assemblies

The peripheral cutting-edge assemblies are started by welding $^3/_4$-in. plate to one leg of a heavy "T"

Fig. 2—Welding of support gussets to the stem of the "T"

section. A $^1/_2$ in. fillet weld is applied with a submerged-arc welding unit, whose funnel is mounted on a radiagraph. The welding speed is 12 ipm, using a fused flux with no alloying contents. The filler metal is $^5/_{64}$-in. diam high-tensile wire. At the same time the plate is being welded to the "T" section, gusset plates are being welded to the other leg on the "T" with a $^1/_2$-in. double fillet weld—Fig. 2.

A subassembly of angle frames is made in a special jig. These frames are 3 x 2 x $^7/_{16}$ in. They are joined by manual shielded-metal-arc welding using low-hydrogen iron powder electrodes and conforming to the specification ASTM-A233 and AWS-7018. These weld are approximately 2 ft long and are generally considered too short for profitable submerged-arc welding. The $^5/_{16}$-in. fillet weld is made at the rate of 8 ipm. Cross members on the subassembly are bolted into position using $^1/_2$- x 1 $^1/_2$-in. bolts. (The purpose of bolting the cross bracing is for ease of removal, at the site, so that reinforcing rods may be positioned freely, after which the cross braces are welded into place.)

The angle frame assembly is then tack welded into position on the plate and the closing or bent plate is lower into position. The bent plates are welded to the stem of the "T" section and subsequently tack welded to the angles from the inside, working overhead—Fig. 3. Tacks are made approximately every 2 ft. The "T" end of the assembly is then lifted by crane until the closing or bent plate is horizontal—Fig. 4. Weight of the assembly at this time is approximately 11 to 15 tons depending upon the unit being made. It is propped into position using heavy timbers and the crane lifts are removed. To prevent sliding during lifting, the complete unit is built on skids with welded stops.

The plates are joined to each other by butt welds. Submerged-arc welding using multilayer welds is required—Fig. 5. A root pass is made, and 100% inspection from the inside of the assembly is conducted to ensure perfect fusion. Visual examination of the backing strip must show a cherry red glow to indicate fusion. The root weld slag is thoroughly removed by automatic chipping. The succeeding passes are then used to fill the groove to at least $^1/_{32}$-in. weld crown. The root pass is made at 13 ipm; the subsequent passes are made at slightly lower speeds.

The assembly is then lowered so that the bottom plate is horizontal, and the angles are welded from the inside, using submerged-arc welding for $^1/_4$-in. fillet welds. The rate of progression is 20 ipm. The unit is then turned completely over so that the angles can be welded to the bent or top plate from the inside. Submerged-arc and manual covered-electrode welding methods are used depending upon the area being welded and the availability of equipment.

The assembly is then turned over so that the "T" is uppermost and the gussets are welded to the stem of the "T," using manual methods.

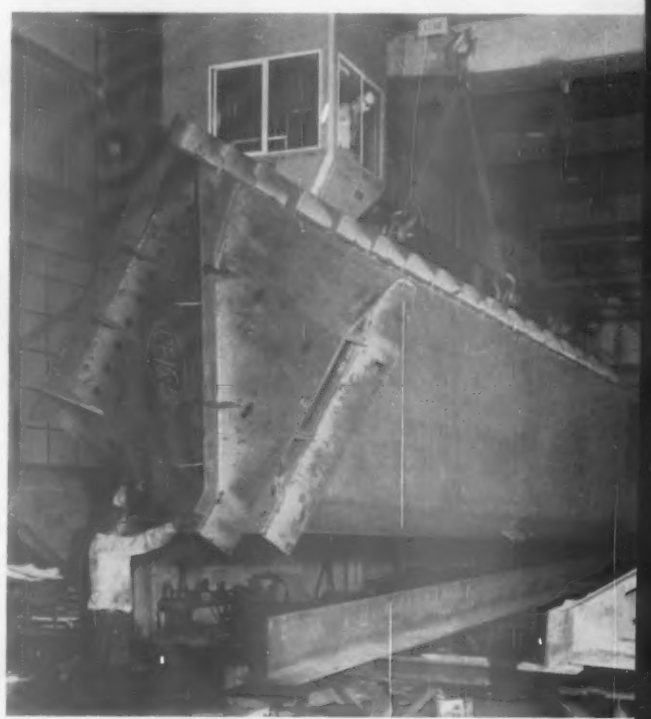


Fig. 4—Maneuvering the huge peripheral sections of the cutting edge takes power and care

Fig. 5—Close-up of weld made by submerged-arc technique

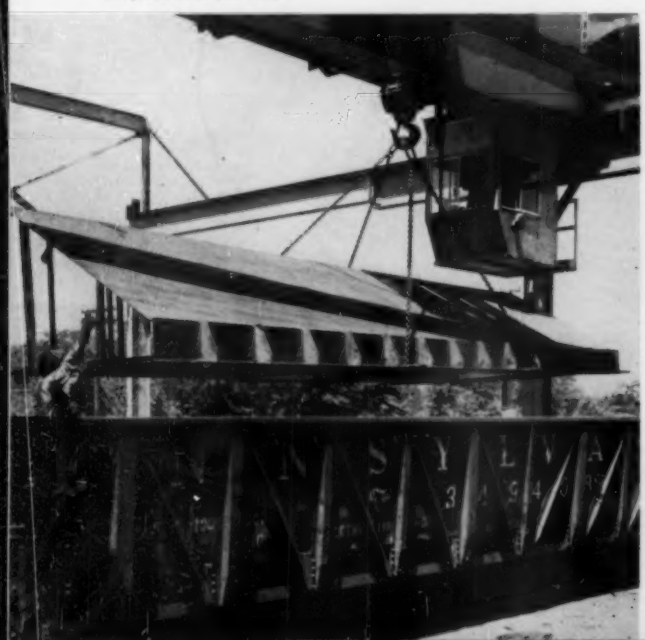
Fig. 3—Subassembly of internal cutting edge sections consists of prebent plates with stiffener angles attached with $^1/_4$-in. double fillet welds

Welding Interior Sections

The interior sections involve the use of $^3/_4$-in. thick plates exclusively as opposed to the $^1/_2$- and $^3/_4$-in. plates used for the peripheral assembly.

Fig. 6—Projection assemblies are fabricated from 1-in. plates and from the connecting link between the peripheral and interior sections

Fig. 7—Loading peripheral sections into boxcar for shipment to job site



The same oxygen-cutting bevelling operation is performed as described previously.

The initial assembly is made by placing a 50- to 60-ft long "T" section on the floor as a jig. The first plate is tack welded into position along the stem of the "T." A backing strip is then applied on the top surface and the next plate moved into place. Each subassembly consists of a bent plate with stiffener angles, welded to the plates by $^1/_4$-in. double fillet welds approximately 30 in. apart. When the complete sub-section has been made, the unit is then raised by crane until the short plate is parallel to the floor. The short angles are welded into place also using a $^1/_4$-in. fillet weld on both sides.

When the two halves of the interior frame are completed, they are brought together in a special jig. Screw jacks are used to achieve a uniform $^1/_4$-in. root opening between the two bent plates. Intermittent off-set tacks are used to hold the backing strip in place. With the assembly on its side, the butt joints on the top plates are then joined by submerged-arc welding. The unit is then turned over, and the butt joints on the bottom are made by the same method. When all plates are fully welded, the unit is turned on end so that the longitudinal seam can be welded. A minimum of three weld passes is required to fill this groove because specifications limit the amount of weld per pass to $^1/_4$-in. and the plate thickness is $^3/_4$ in. Inspection is made from within during the root pass to be sure of complete fusion.

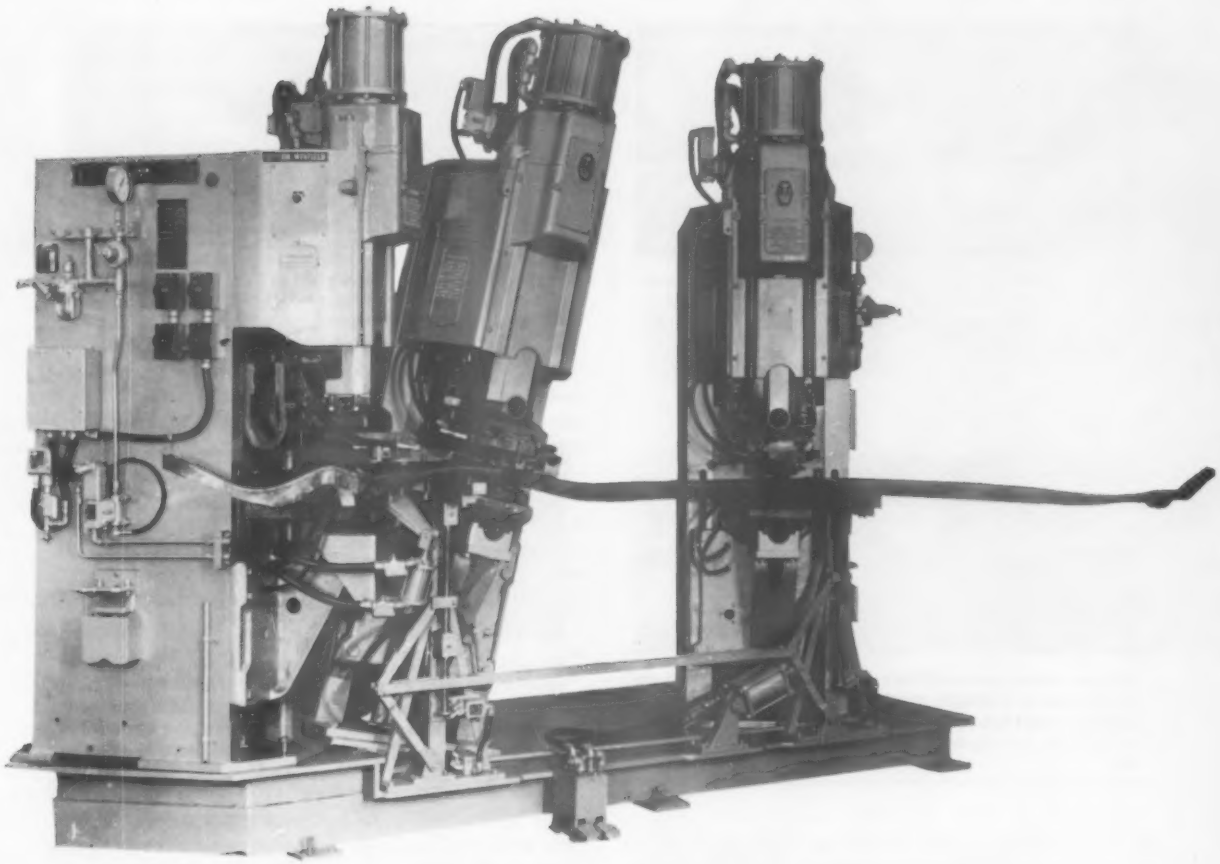
Projection or Connecting Assemblies

The design of the cutting edge requires the joining of assemblies of completely different geometry. These shapes are joined at right angles. Plates, which are 1-in. thick, are used in the fabrication of these projection assemblies—Fig. 6. Extreme care must be taken to assure fit between joining surfaces. Restraining devices such as gussets are used to maintain close fit of assembly, and extreme care is taken to avoid distortion. Projection assemblies are fabricated separately but joined to either a peripheral or interior section prior to shipment to the job site—Fig. 7.

The Verrazano-Narrows Bridge

The Verrazano-Narrows Bridge now being built is a suspension bridge which will have the longest span in the world—a 4260 ft center to center of towers or 60 ft longer than the Golden Gate suspension bridge in San Francisco. The bridge from end to end of anchorages will be 7150 ft long. The two supporting steel towers will be 680 ft high. Total cost of the project is estimated to be $325 million.

Scheduled for completion in early 1965, the new bridge will link parkways and expressways of Long Island, Westchester and New England with the advanced arterial systems in Staten Island and New Jersey, enabling thru-traffic to by-pass the congested streets of Manhattan.



The projection welding of attachments to the side rail of an automobile frame—three press welders are arranged on a subbase equipped with work locator devices

Information is presented to help select equipment and variables for

Projection Welding Low-Carbon Steel Using Embossed Projects

BY J. F. HARRIS AND J. J. RILEY

Projection welding as distinguished from spot welding is an economical process for weldment fabrication, especially when several welds are required in a localized area. Knowledge of the welding process and its limitations promotes satisfactory results. The background involves weld formation, electrode and projection design, and effects of force, current and time. Thus this paper presents data to assist in the selection of welding equipment and process variables for welding low-carbon steels with embossed projections in the thickness range of 0.011 to 0.245 in. The data have been divided into three thickness ranges: 0.011 to 0.019 in., 0.022 to 0.135 in. and 0.153 to 0.245 in., as each range presents different welding problems.

The formation of projection welds, the dies or electrodes used and the effects of weld variables are explained. Recommended weld schedules are also provided, based upon data and macrophotographs. Finally, mention is made of up-slope current control, forge force and other equipment accessories to ease the processing of projection welds.

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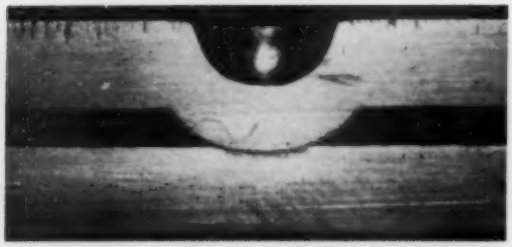
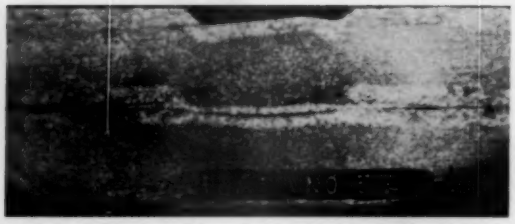
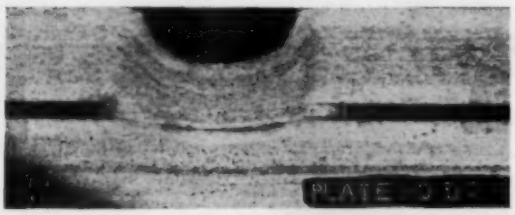


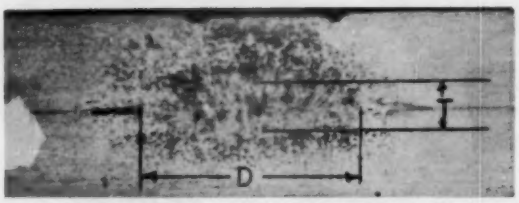
Stage 1—Cold set down and no current. Original projection height of 0.050 in. decreases 0.010 in. caused by 0.008 in. indentation and 0.002 in. projection collapse. Sheet separation is 0.040 in.



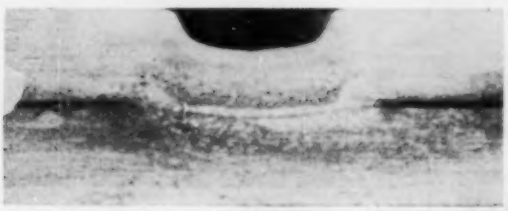
Stage 5—Ten cycle weld time and tensile shear strength of 2500 lb. with sheet separation of 0.002 in.—this is the last stage of welding without nugget formation.



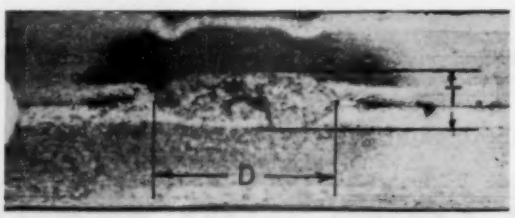
Stage 2—One cycle weld time. Pressure weld forms with tensile shear strength of 1050 lb. Sheet separation is 0.010 in. (With two cycle weld time, tensile shear strength of 1750 lb. is obtained, with sheet separation of 0.007 in.)



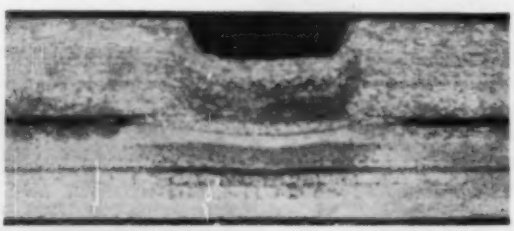
Stage 6—Twelve cycle weld time with strength of 3100 lb., with sheet separation of 0.001 in. Note that nugget formation has started and that the nugget diameter is 0.150 in. (With fourteen cycle weld time, the strength is 3200 lb., with no sheet separation. The nugget diameter is 0.160 in.)



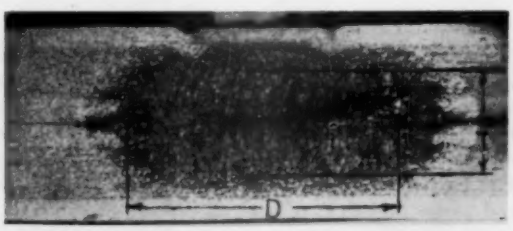
Stage 3—Four cycle weld time—tensile shear strength of 2300 lb. and sheet separation of 0.005 in.



Stage 7—Using a recommended sixteen cycle weld time, tensile shear strength reaches 3700 lb., with no sheet separation. The nugget diameter is 0.160 in.



Stage 4—Six cycle weld time resulting in tensile shear strength of 2600 lb. wherein sheet separation is 0.005 in. (Eight cycle weld time gives strength of 3000 lb., with sheet separation equal to 0.002 in.)



Stage 8—At twenty cycle weld time, the tensile shear strength reaches 4000 lb., and the nugget diameter is 0.300 in. (Stage 8 indicates an increase in nugget size with increased weld time.)

Fig. 1—Projection weld formation in double thickness of 0.092-in. thick low-carbon steel using Schedule A of Table 2

Advantages of Projection Welding

The principal advantages of projection welding are:

1. A number of welds can be made simultaneously with one operation of the welding equipment.
2. The number of welds in a specific area may be increased, as compared to normal spot-welding techniques, i.e., the center line distance, or pitch, between projection welds may be less than spot welds in the same material thickness.
3. Electrodes used in projection welding require little maintenance in the way of cleaning and reshaping as required in resistance spot welding.
4. Tooling construction usually combines electrode, and/or die, die holder and locators in one assembly. This assembly as mounted on the welder platens both locates workpieces and welds the weldment.
5. Weldments composed of thickness ratios of 3 (or more) to 1 are sometimes difficult to spot weld. The flexibility of selecting the projection size and its location allow ratios of 6 (or more) to 1 to be readily projection-welded.
6. Weldments requiring a minimum surface marking on one side are achieved by embossing projections into the other part of the weldment. The slight bump raised in welding (if objectionable) can be removed by a simple metal finishing operation.

Projection Weld Formation

A study of the formation of a projection weld shows the need for proper projection formation and adequate resistance-welding equipment. The projection collapse during welding is almost complete at 20% of the weld time. The welding tooling must follow this movement to apply the proper electrode force and to avoid loss of projection by excessive metal expulsion. Eight stages may be said to be encountered in projection weld formation. These are illustrated by a series of macrophotos in Fig. 1.

In Stages 2 to 4, the projection is collapsing and bonding is taking place as evident by the shear strength. At Stage 6, on the other hand, the interface has disappeared and slight nugget formation is evident. Many projection welds end at this stage and possess consistent shear strength. As the current continues to flow, the nugget formation becomes more evident in Stage 7. Further current flow time will substantially increase the nugget diameter and penetration evident in Stage 8.

Projection weld formation depends in part on current magnitude. Unless the magnitude is sufficient for definite nugget formation, the weld appearance will be typified by Stage 6, regardless of the weld time. If four projection welds are made simultaneously using a common electrode to furnish the current and force, it will be difficult to form nuggets of equal size. The difficulty increases with the number of projections. Special tooling to aid equal distribution of force and current, examples of which are shown in Figs. 2 and 3, will improve the equality of nugget diameters.

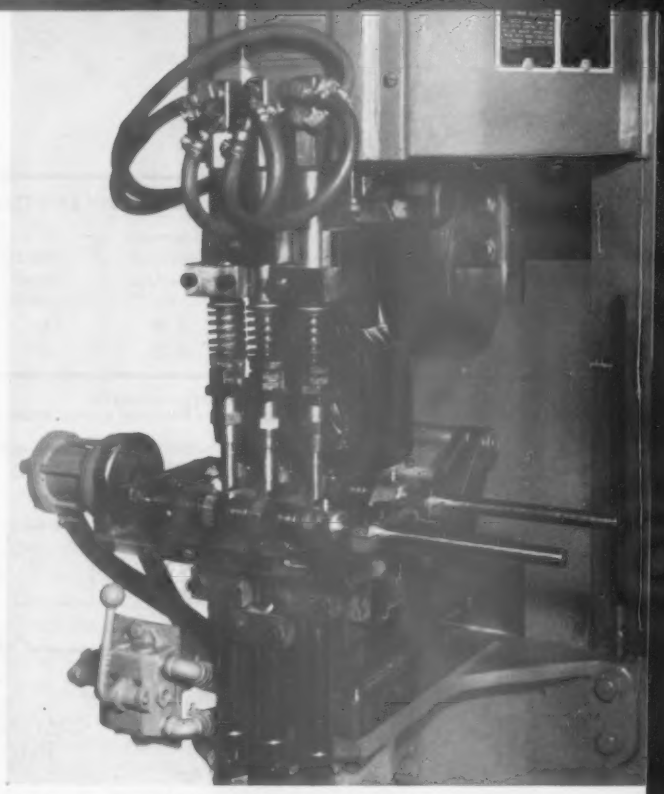


Fig. 2—Spring-loaded low inertia electrode holders provide an economical means of obtaining a uniform force pattern and aid in equal current division

Fig. 3—Grease-equalized electrode holders equalize the force pattern and aid current distribution—may be used when the force magnitude exceeds the spring loaded type in Fig. 2. Ten projection welds are made simultaneously with this tooling

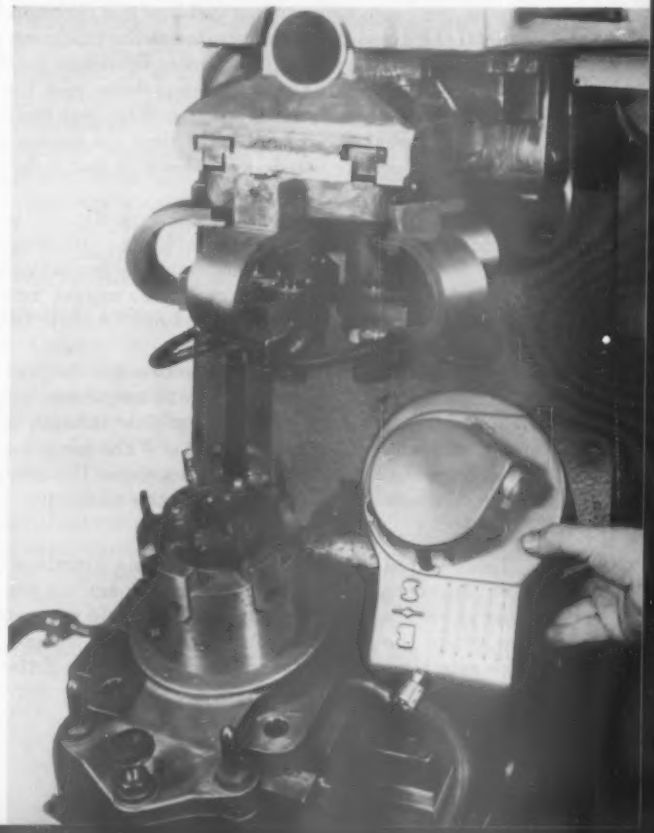
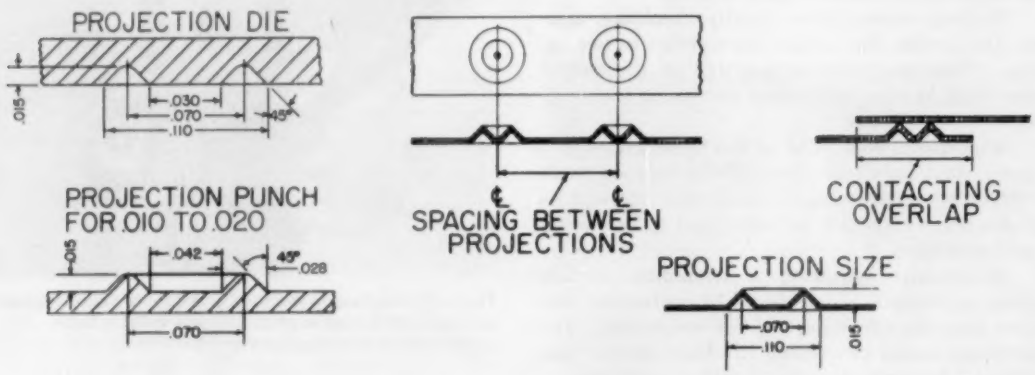


Table 1—Projection Welding of Low-carbon[a] Steel[b] 0.010 Through 0.019 in. Thickness (Two Equal Thicknesses)

t, in.	USS gage	Minimum spacing, C_L to C_L, in.	Minimum contact overlap, in.	Weld time, cycles[c]	Electrode force, lb[d]	Welding current, amp	Shear strength, for 1 projection	lb each weld for 2 or more projections[e]
0.011	31	0.31	0.25	6	110	5200	190	145
0.019	26	0.31	0.25	6	225	5400	400	280

[a] Low-carbon steel SAE 1010, 42,000–55,000 psi ultimate.
[b] Surface of steel may be oiled lightly but free from grease, scale and dirt.
[c] Based on 60 cps.
[d] Electrode force contains no factor to further form poorly made parts.
[e] Approximate strength per projection—depends on joint design.



Influence of Welding Variables in Projection Welding

Welding Current

The welding current must be of sufficient magnitude to cause fusion before projection collapse. The rigidity of the projection against collapse is a function of metal thickness becoming greater as the thickness increases. With greater rigidity more flexibility prevails for adjusting the current magnitude and its flow pattern. In thin materials (0.020 in. and less) the range of weld current and weld time are narrow. Workable values are listed in Tables 1, 2 and 3 dependent on the metal thickness.

Nugget formation (beyond Stage 6 in Fig. 1) is seldom necessary in projection welding. Welding schedules listed in Tables 1, 2 and 3 for one projection will produce well defined nuggets. The nugget formation approaches Stage 6 as schedules for three or more projections are used.

The tendency for metal expulsion of a specific projection size is increased as the current magnitude increases. The welding current must flow through a small contact area (Stage 1 in Fig. 1). The use of an up-slope control, which gradually increases the current magnitude with time, minimizes this problem.

Electrode Force

The electrode force has four principle functions:

1. It must hold the projection firmly against the other sheet during the initial period of weld current flow where the current density is high and the collapse rate is rapid. A pressure loss will result if the welding electrode cannot follow the projection collapse. This loss is evident by expulsion of the molten metal.

2. The electrode force must cause complete collapse after welding, so the resulting sheet separation is small. The height of the projection has a bearing on the magnitude of the electrode force, assuming the same projection base diameter. The higher the projection, the higher must be the electrode force for complete collapse.

3. The electrode force has a distinct influence on the degree of porosity in the weld nugget. It must be low enough to give proper projection collapse and yet high enough to produce comparatively sound welds. In some cases, especially in the thicker materials, these requirements are so divergent that a weld force is recommended to make the welds; and a *forge* force, applied after current flow, is recommended to minimize porosity.

4. The suitable dynamic force characteristic must prevail without producing excessive initial impact force. The impact force should be no greater than the welding force, otherwise the initial contact area will change, influencing the welding results.

Evidence of excessive impact force is the formation of ring welds, or fusion around the periphery of the projection leaving a partially welded center. If one projection is being welded, it must resist the total impact force. As the number of projections is increased, the impact force is reduced on each one. Thus considering a specific machine, the speed of the ram can be increased as the number of projections

Table 2—Projection Welding of Low-carbon Steel 0.022 to 0.135-in. Thickness (Two Equal Thicknesses)

Thickness, t in.[d]	USS gage	Projection size, in. Diameter	Projection size, in. Height	Minimum spacing, C_L to C_L, in.	Minimum contact overlap, in.	Welding Schedule A for single projection[a] Weld time, cycles[e]	Electrode force, lb[f]	Welding current, amp	Shear, lb[g]	Welding Schedule B for 1–3 projections, per projection[b] Weld time, cycles[e]	Electrode force, lb[f]	Welding current, amp	Shear, lb[g]	Welding Schedule C for 3 or more projections, per projection[c] Weld time, cycles[e]	Electrode force, lb[f]	Weld current, amp	Shear, lb[g]
0.022	25	0.090	0.025	0.38	0.25	3	150	4,400	370	6	150	3,850	325	6	80	2900	290
0.028	23	0.090	0.025	0.38	0.25	3	195	5,500	500	6	150	4,450	425	8	100	3300	340
0.034	21	0.110	0.035	0.50	0.38	3	240	6,600	700	6	150	5,100	525	11	125	3800	425
0.043	19	0.110	0.035	0.50	0.38	5	330	8,000	1060	10	210	6,000	875	15	160	4300	720
0.049	18	0.140	0.038	0.75	0.50	8	400	8,800	1300	16	270	6,500	1100	19	220	4600	875
0.061	16	0.150	0.042	0.75	0.50	10	550	10,300	1800	20	365	7,650	1575	25	330	5400	1225
0.077	14	0.180	0.048	0.88	0.50	14	800	11,850	2425	28	530	8,850	2150	34	470	6400	1750
0.092	13	0.210	0.050	1.06	0.62	16	1020	13,150	3250	32	680	9,750	2800	42	610	7200	2325
0.107	12	0.240	0.055	1.25	0.75	19	1250	14,100	3850	38	830	10,600	3450	50	740	8300	2900
0.123	11	0.270	0.058	1.50	0.81	22	1500	14,850	4800	45	1000	11,300	4200	60	900	9200	3600
0.135	10	0.300	0.062	1.63	0.88	24	1650	15,300	5500	48	1100	11,850	4850	66	1000	9900	4250

[a] Schedule A is usable for welding more than one projection if current is decreased but excessive weld expulsion may result and power demand will be greater than Schedules B or C.
[b] Schedule B is usable for welding more than three projections but some weld expulsion may result and power demand will be greater than Schedule C.
[c] Schedule C is usable for welding less than three projections with weld current increased approximately 15% and possible objectionable final sheet separation.
[d] Low-carbon steels 42,000–55,000 psi ultimate, SAE 1005–1010. Surface of steel may be oiled lightly but free from grease, scale and dirt.
[e] Based on 60 cps.
[f] Electrode force contains no factor to further form poorly made parts.
[g] Strength per projection depends on joint design.

increase and maintain the impact force absorbed by each projection constant (see Appendix A).

The electrode force has an influence on weld size. The size will increase within limits with decreasing electrode force if the welding current is held constant.

Weld Time

The value of weld time will be dependent on the weld current and projection rigidity. As a working approximation, the relationship can be expressed as: $I^2t = I_1^2t_1$, in which I is the current in amperes at time t in seconds. I_1 is the current in amperes at time t_1 in seconds.

A working range of adjustment is indicated in Table 2. Projection welds made with the shortest times are not necessarily of the best quality. A short weld time requires a correspondingly high welding current. The high current must initially pass through a small contact area, raising the current density and increasing the tendency for expulsion.

This problem is aggravated by the use of multiple projections as the height tolerance will vary the initial contact area per projection. Consequently, for welding multiple projections, it is suggested that longer weld times be used. Up-slope control is recommended if available. Projection welding, unlike spot welding, requires considerable ram movement while the projection is collapsing. In a normal weld, the collapse is essentially complete in the first 20% of the weld time period. Thus, as the over-all weld time is shortened, the welding ram must follow up at an increasingly higher speed. This can be a severe requirement for a large press welder (Fig. 4) with its inherent mass and inertia.

Electrode or Dies

Using electrodes of proper design, shape and alloy is a factor in making projection welds but of less influence than making spot welds. There are two basic types of electrodes:

1. Large flat surface electrodes, made from bar stock.

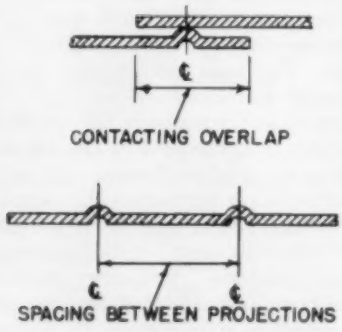
2. A series of local contact surfaces (Fig. 5) made by relieving a bar between projections or by brazing inserts of hard copper alloy to the bar.

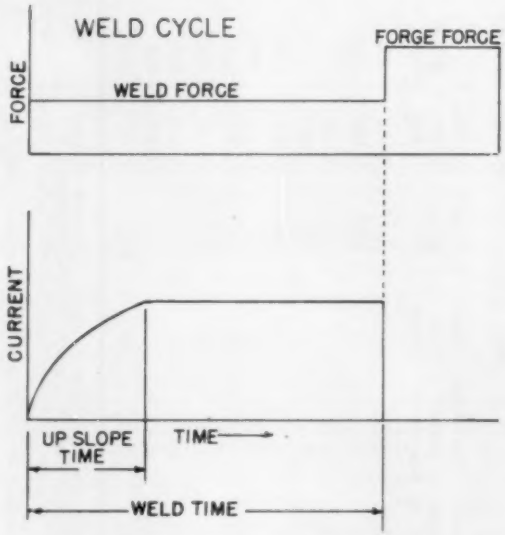
Flat electrodes are not recommended on weldments which are distorted from the projection forming operation. The distortion prevents the weld force and current from entering directly above the projections

Table 3—Projection Welding of Low-carbon[a] Steel[b] 0.153 to 0.245-in. Thickness (Two Equal Thicknesses)

Thickness		Projection size		Minimum		Electrode force weld	Electrode pound forge[c]	Up slope[d]	Weld time[d]	Welding current, amp	Shear strength, lb[e]
In.	USS gage	Diameter, in.	Height, in.	C_L to C_L spacing, in.	Overlap, in.						
Schedule A, welding normal size welds											
0.153	9	0.330	0.062	1.75	0.9	2000	4000	15	60	15,400	7,500
0.164	8	0.350	0.068	1.80	0.95	2300	4600	15	70	16,100	8,100
0.179	7	0.390	0.080	1.90	1.0	2630	5260	20	82	17,400	9,500
0.195	6	0.410	0.084	2.00	1.05	2930	5860	20	98	18,800	11,300
0.210	5	0.440	0.092	2.10	1.15	3180	6360	25	112	20,200	12,500
0.225	4	0.470	0.100	1.30	1.20	3610	7220	25	126	21,500	15,000
0.245	3	0.530	0.112	2.50	1.30	3900	7800	30	145	23,300	17,300
Schedule B, welding small size welds											
0.153	9	0.270	0.058	1.60	0.75	1400	2800	15	60	11,100	5,100
0.164	8	0.290	0.062	1.65	0.80	1425	2850	15	70	11,800	5,500
0.179	7	0.310	0.067	1.70	0.85	1500	3000	20	82	12,800	6,500
0.195	6	0.330	0.072	1.75	0.90	1600	3200	20	98	13,900	7,700
0.210	5	0.350	0.077	1.80	0.95	1730	3460	25	112	14,900	8,500
0.225	4	0.370	0.082	1.90	1.00	1870	3740	25	126	16,000	10,400
0.245	3	0.390	0.088	2.10	1.10	2100	4200	30	145	17,300	12,000

[a] Low-carbon steel SAE 1005–1010, 42,000–55,000 psi ultimate.
[b] Surface of steel may be oiled lightly but free from grease, scale and dirt.
[c] On single pressure welds use only weld force as electrode force. Electrode force contains no factor to further form poorly made parts.
[d] Time in cycles—60 cps base.
[e] Approximate shear strength per projection—depends on joint design.





and results in unequal current and force division. Flat electrodes are advisable when welding a few projections in a localized area.

Flat electrodes or local contact surface electrodes made from one piece having acceptable life are fabricated from RWMA Class 2, Class 3 or Class 4 alloys. Class 3 is recommended. The localized contact area type of electrode tends to equalize the total current and pressure in spite of distortion or tolerance of the weldment. This type of electrode is recommended as best for all projection welding, and especially in those applications involving four or more projections.

If a hard electrode material is required, an economical solution is to use a composite electrode of copper backing with the appropriate facing. The facing suggested here is a copper-tungsten alloy brazed to the copper under controlled conditions (Fig. 5). The ideal electrode alloy is as hard as possible and does not crack or cause surface burning on the weldment. If cracking or surface burning is encountered, a softer alloy with higher conductivity and ductility is required.

While it is not the intent here to discuss the details of electrode design, two other factors must not be overlooked. These are the desirability of water cooling and the need for clean and firmly bolted contacting surfaces. Water cooling—either directly on the electrode or indirectly on the electrode holder—is desirable to avoid overheating and resulting oxidation. This is important in the care of precipitation-harden-

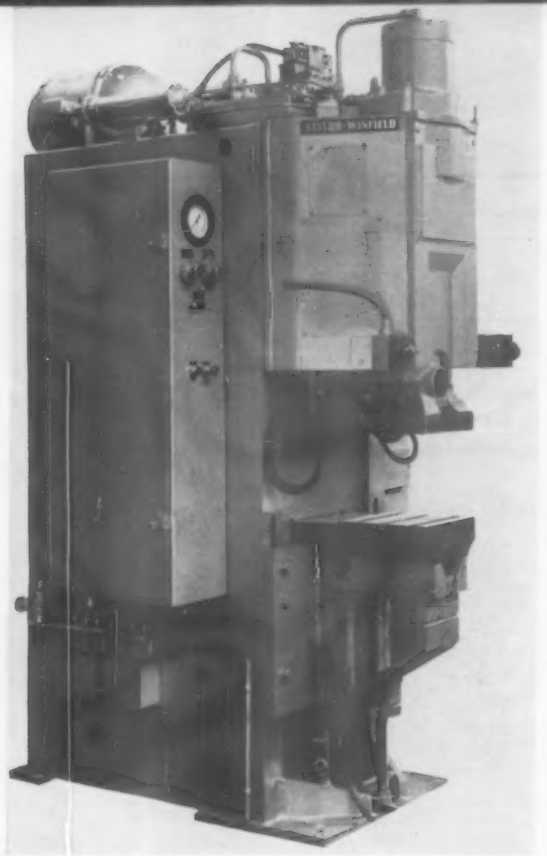


Fig. 4—Hydraulically operated press welder with 18,000 lb force

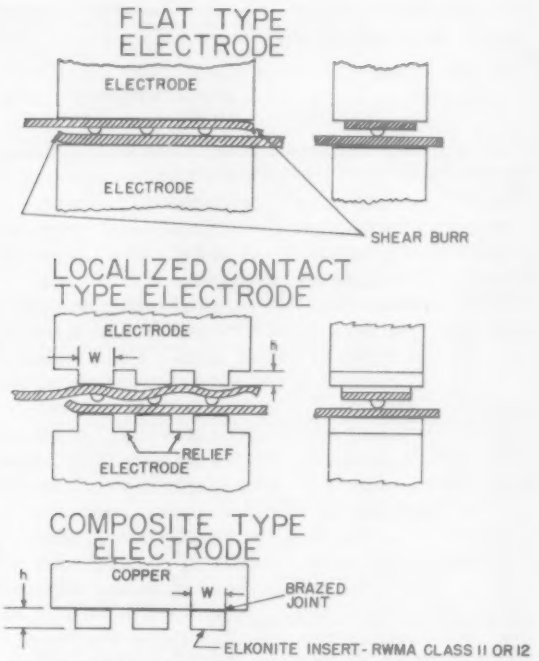


Fig. 5—Projection welding electrodes (W is approximately 3 times the projection diameter but not less than 0.5 in.; h ranges from 0.12 to 0.25 in. and Elkonite insert diameter equals W)

ing type alloys which lose their hardness above a specific temperature. With contacting surfaces, the reason for cleaning and firmly bolting all together is to reduce the surface contact resistances and avoid excessive heating.

Parts Preparation

Inferior welds with varying degrees of expulsion and surface marking will result if the weldment is not clean or free of grease, rust, scale or dirt. A slight oily surface is not objectionable.

If a number of projections are to be welded simultaneously, the variation in height between projections should be confined to 3% of the height of the projection. Excessive variation in height will cause expulsion and will exaggerate the formation of unequal weld diameters.

In preparing the weldment, it is imperative that shearing burrs (Fig. 5) be eliminated. As the projection collapses, burrs form shunting paths for both current and force. Uncontrolled shunting makes it impossible to make consistent welds.

In any welding operation, the less the variation in part tolerance before welding, the more consistent the weldments will be. The welding equipment will not successfully finish-form the weldment. This mechanical operation has a tremendous effect on the equalization of the electrode force over each projection in a multiple projection weld. Without proper equalization, the weld quality will vary widely.

Projection Size and Shape

There are many opinions regarding the proper size and shape of embossed projections. A compromise is required between the best formation for welding and ease of mechanical forming. The majority of projections recommended in this paper are made with nonbottoming punches. This avoids tool breakage if material thickness varies slightly. In thin materials, the annular shape projection is suggested although it is not difficult to form. The simple, dimple type would not weld properly.

In heavy materials, a recessed type of projection is suggested to minimize sheet separation. It would be used if the simpler type projection produced too much separation in a specific application.

Projection Welding of Thin Materials

Thickness Range of 0.011 to 0.019 in.

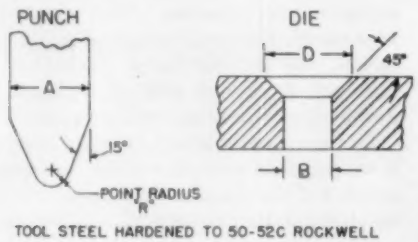
Table 1 shows projection sizes and weld schedules for the thickness range of 0.011 to 0.019 in. A small annular projection with its greater resistance to cold collapse is used in place of the simpler spherical dome.

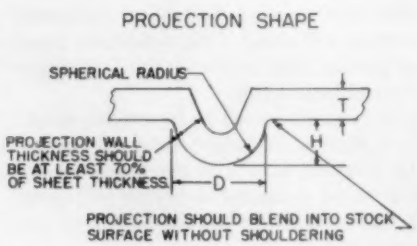
Weldments made of thin materials and fabricated by projection welding introduce additional problems not common to those made of thicker metal. The selection of welding equipment with low impact force and rapid follow up is necessary. The required electrode force should be near the maximum capacity of the equipment. If only a larger machine is available or the required electrode force is at its minimum capacity, the follow-up problem can be solved by adding tooling such as spring loaded electrode holders (Fig. 2). The holders have the low inertia and fric-

Table 4—Punch and Die Dimensions[a]

USS gage	Thickness, T	Projection		Punch		Die	
		Height, H, ±2%	Diameter, D, ±5%	Diameter, A	Point radius, R, ±0.002	Hole diameter, B, ±0.005	Chamber diameter, D
For making spherical dome projections							
25–21	0.022–0.034	0.025	0.090	0.375	0.031	0.076	0.090
20–19	0.036–0.043	0.035	0.110	0.375	0.047	0.089	0.110
18–17	0.049–0.054	0.038	0.140	0.375	0.047	0.104	0.130
16–15	0.061–0.067	0.042	0.150	0.375	0.062	0.120	0.150
14	0.077	0.048	0.180	0.375	0.062	0.144	0.180
13	0.092	0.050	0.210	0.500	0.078	0.172	0.210
12	0.107	0.055	0.240	0.500	0.078	0.196	0.240
11	0.123	0.058	0.270	0.500	0.094	0.221	0.270
10	0.135	0.062	0.300	0.500	0.109	0.250	0.300
9	0.153	0.062	0.330	0.500	0.125	0.270	0.330
8	0.164	0.068	0.350	0.500	0.141	0.297	0.360
7	0.179	0.080	0.390	0.500	0.156	0.328	0.390
6	0.195	0.084	0.410	0.500	0.156	0.338	0.410
5	0.210	0.092	0.440	0.500	0.187	0.358	0.440
4	0.225	0.100	0.470	0.500	0.187	0.368	0.470
3	0.245	0.112	0.530	0.500	0.187	0.406	0.530
For small projections in heavy gages							
9	0.153	0.058	0.270	0.500	0.109	0.188	0.270
8	0.164	0.062	0.290	0.500	0.109	0.207	0.290
7	0.179	0.065	0.310	0.500	0.109	0.227	0.310
6	0.195	0.068	0.330	0.500	0.125	0.250	0.330
5	0.210	0.068	0.350	0.500	0.141	0.272	0.350
4	0.225	0.072	0.370	0.500	0.141	0.390	0.370
3	0.245	0.075	0.390	0.500	0.156	0.312	0.390

[a] All dimensions are in inches.





tion necessary for following the projection collapse.

There is not much flexibility in weld timing, since desirably short times for welding necessitate extremely fast follow-up and require machine designs which would have to sacrifice other desirable features.

Two values of shear strength are shown in the schedule chart of Table I. The single projection value can be duplicated or exceeded. However, the anticipated shear strength for each projection of a cluster of two or more depends so much on the mechanical joint design that the listed values can serve only as a guide.

Thickness Range of 0.022 to 0.135 in.

Material thicknesses of 0.022 to 0.135 in. are the range where projection welding excells. Table 4 lists the sizes of projection and the tools to produce them. Recommended welding schedules are listed in Table 2. Schedule A is given for welding one projection, Schedule B for one to three projections, and Schedule C for three or more projections. These schedules progressively indicate lower values of electrode force and welding current with increasing weld time.

Figure 6 shows a series of photomacrographs of welds in three gages of materials made using Schedules A, B and C of Table 2. These welds illustrate some of the variation that may be expected from these schedules. Test results are tabulated in Table 6. As may be seen, the average weld shear strength

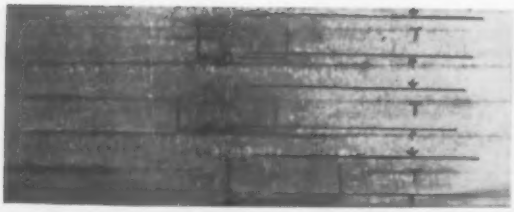


Fig. 6a, b and c—Two pieces of 0.030-in. LC steel

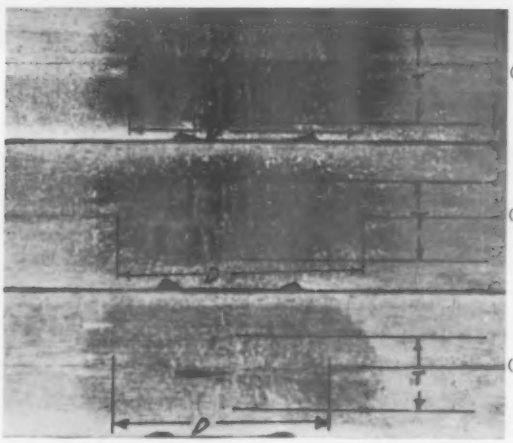


Fig. 6d, e and f—Two pieces of 0.065-in. LC steel

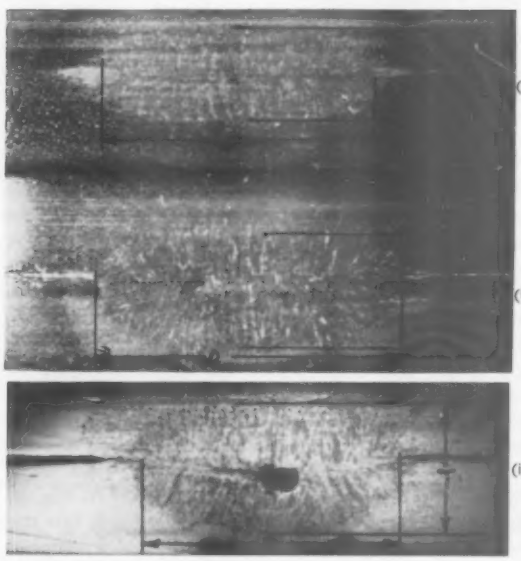


Fig. 6g, h and i—Two pieces of 0.097-in. LC steel

For 0.030-in. material—Schedule A, D = 0.100 in., T = 0.030 in.; Schedule B, D = 0.100 in., T = 0.025 in.; and Schedule C, D = 0.100 in. and T = 0.030 in. For 0.065-in. material—Schedule A, D = 0.203 in., T = 0.082 in.; Schedule B, D = 0.216 in., T = 0.70 in.; and Schedule C, D = 0.190 in. and T = 0.064 in. For 0.097 in. material—Schedule A, D = 0.250 in., T = 0.080 in.; Schedule B, D = 0.300 in., T = 0.110 in.; and Schedule C, D = 0.250 in., T = 0.100 in.

Fig. 6—Projection welds made using Schedules A, B and C of Table 2 ("D" is nugget diameter, and "T" is nugget thickness)

is similar in all schedules. The strengths listed in Schedule A are higher than in Schedules B or C to imply that single projections will possess more consistent strength than the average of multiple projections.

Schedule A welds require the highest force and current per projection, variables which dictate the equipment size. These values can be expanded for welding more than one projection if the weld time is increased. When Schedule A is used for multiple projection welding, a weldment be made of 18 gage or thicker material is advisable. As noted in Table 8 which tabulates the results of multiple projection welding, the 0.032-in. thickness could not be consistently welded because of expulsion.

Schedule B is considered the normal operating schedule. The weld strength may be slightly less than that for Schedule A, but the latitude in welding variable adjustments is greater. Variation of any item such as force, current or time may be greater and still produce usable weldments. Schedule C is considered for 3 or more projections. Use of this schedule allows the size of welding equipment and the power demand to be a minimum. In addition, the normal dimensional tolerance and surface conditions will have a minimum effect on weld quality if the long weld time schedule is used. Nevertheless the variation in weld strength will be greatest with Schedule C. Single projection welds can be made using the welding variable values shown in Schedule C but the weld current will increase approximately 15%.

The results of using multiple projection welds are tabulated in Table 8. These welds were made at a fixed projection spacing, in three gages, and welding three projections at one time. Except for current magnitude which was adjusted to give satisfactory welds, the welding variables were selected from Table 2. Note that the current values for Schedule A were reduced about 30%.

In normal weldment design, the strength per projection can vary appreciably as long as the weldment shows sufficient strength when physically destroyed. Thus if a slug of metal is broken from the base metal around each projection, the part is considered satisfactory even though these slugs vary in size. The over-all strength of the assembly should be the criterion for design in weldments containing multiple projections. Under average production conditions the weld size among projection welds will vary from weldment to weldment but the over-all strength will be consistent in a properly designed assembly.

Thickness Range of 0.153 to 0.245 in.

Weldments made by projection welding in the thickness range of 0.153 to 0.245 in. are limited. The large size equipment required coupled with the power demand requirements reduces the number of applications. The welding technique is not critical. Table 4 lists the sizes of projections. Recommended welding schedules are listed in Table 3.

Schedule A lists the technique for normal size welds. Schedule B is confined to smaller size welds, which

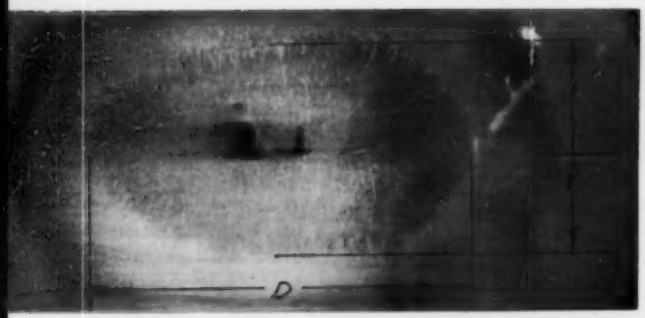


Fig. 7a—Projection size 0.530 in. in diam and 0.115-in. high. The resultant nugget is 0.680 in. in diam and 0.320 in. thick. The tensile shear strength was 17,300 lb

Fig. 7b—Projection size 0.390 in. in diam and 0.086-in. high. The resultant nugget is 0.450 in. in diam and 0.300-in. thick. The tensile shear strength was 12,000 lb

Fig. 7—Normal and small projection welds in two pieces of 0.245 in. low-carbon steel made using Schedules A and B of Table 3

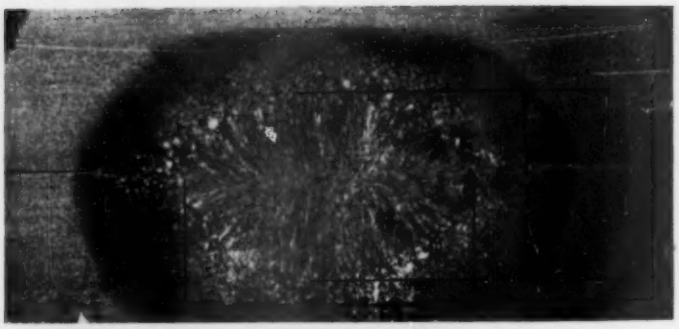


Fig. 8a—Forged force of 4200 lb applied at end of weld time. The nugget thickness is 0.300 and 0.450 in. diam

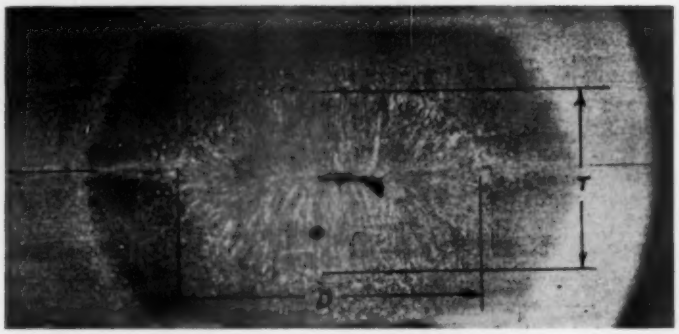


Fig. 8b—Same size of weld made without forge force. The increase in porosity is evident

Fig. 8—Forged and unforged welds in double thickness of 0.245 in. thick low-carbon steel using small projection of Schedule B in Table 3—original projection size diameter 0.390 by 0.086 in. high

can be fabricated on smaller welding equipment and at less power. The welds made from Schedule A are larger and therefore stronger than those of Schedule B. The small size welds are recommended when two or more are required. Fig. 7 is a photomacrograph of a normal size and small size weld in 0.245-in. thick material made using weld force only.

Projection welding in this thickness range emphasizes three factors. The porosity of the weld increases. The sheet separation increases as it is difficult to obtain complete projection collapse. The equipment involved has more sluggish follow-up because of its size. This may cause increased metal expulsion while welding. Weld porosity is seldom eliminated. It is minimized by applying a forge force at the end of weld time. The weld magnitude of electrode force is applied during welding to reduce the current required and to allow proper projection collapse. The forge force is applied immediately after weld time.

The shear strength of the weld is similar whether or not it is forged. It is probable that less variation would exist if forge force is used. Figure 8 is a photomacrograph of forged and unforged welds made from the small diameter projections of Table 4 and Schedule B of Table 3.

Sheet separation is minimized by two procedures, either through the use of forge force or through the use of a recessed type of projection as shown in Table 5. The tools are difficult to manufacture. A coining operation is needed. The press tonnages to make recessed projections in 0.179 and 0.245-in. thicknesses were 40,000 and 60,000 lb, respectively.

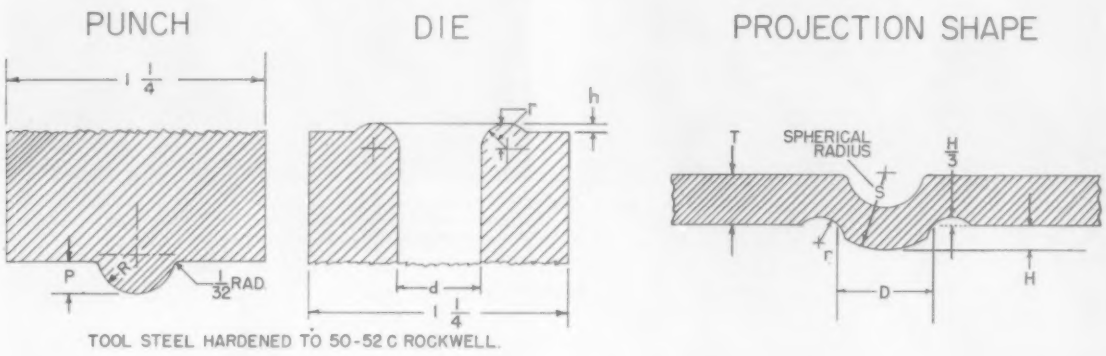
Recessed projections limit the strength of the weld. The metal, which flows into the recess cavity, does not appreciably contribute to weld strength. The use of the recess allows complete set down at lower forces than when using standard embossed projections. The effect of using a recessed projection in 0.245 and 0.179-in. material is illustrated in Fig. 9. Basically Schedule B of Table 3 was used, but the projection size corresponded to Schedule A to emphasize the effect of a recess in reducing sheet separation.

Metal expulsion resulting from sluggish ram movement is compensated for allowing the welding current to increase gradually by using up-slope control. This procedure decreases the rate of follow-up necessary to maintain weld force. All the welds illustrated in this paper were made on equipment containing air diaphragms and roller bearing rams to eliminate the effect of cylinder friction; an example is shown in Fig. 10.

Table 5—Punch and Die Dimensions[a] for Making Recessed Projections

USS gage	Thickness, T	Projection: Height, H, ±2%	Projection: Diameter, D, ±5%	Projection: Radius, S	Punch: Radius, R, ±0.005	Punch: Height, P, ±2%	Die: Hole diameter, d, ±0.005	Die: Recess radius, r, r = S/3	Die: Recess height, h, h = H/3
11	0.123	0.058	0.270	0.196	0.094	0.075	0.221	0.065	0.019
10	0.135	0.062	0.300	0.215	0.109	0.081	0.250	0.072	0.020
9	0.153	0.064	0.330	0.235	0.125	0.085	0.270	0.078	0.021
8	0.164	0.068	0.360	0.248	0.141	0.091	0.297	0.083	0.023
7	0.179	0.080	0.390	0.274	0.156	0.104	0.328	0.091	0.027
6	0.195	0.084	0.410	0.286	0.156	0.111	0.338	0.095	0.028
5	0.210	0.090	0.440	0.305	0.187	0.120	0.358	0.101	0.030
4	0.225	0.100	0.470	0.325	0.187	0.132	0.368	0.108	0.033
3	0.245	0.112	0.530	0.365	0.187	0.146	0.406	0.121	0.037

[a] All dimensions are in inches.



TOOL STEEL HARDENED TO 50-52 C ROCKWELL.

Table 6—Test Results of Welds Using Single Projections

Equal thickness	Schedule	Weld time, cycles	Electrode force, lb	Welding current, amp	Average tensile shear, lb	Variation[a]	Nugget diameter, in.	Comments on shear test
0.032	A	3	200	6,900	644	0.279	0.125	80% pull buttons[b]
	B	6	150	4,900	630	0.300	0.125	72% pull buttons
	C	11	125	4,450	679	0.120	0.125	All buttons
0.065	A	10	550	10,900	2296	0.150	0.187	All buttons
	B	20	375	7,000	2324	0.150	0.187	All buttons
	C	25	330	6,600	2322	0.190	0.187	All buttons
0.097	A	16	1020	13,600	3660	0.080	0.250	All buttons
	B	32	680	10,000	3792	0.110	0.250	All buttons
	C	42	610	8,200	3618	0.190	0.250	85% pull buttons

[a] Variation = maximum shear-minimum shear/average.
[b] Expulsion while welding resulted in some welds producing an abnormally high variation.

NOTES:
1. Schedules A, B and C refer to Schedules in Table 2. Projection size as per Table 4.
2. The average shear strength was determined by testing 24 welds.
3. The metallurgical structure of representative welds is shown in Fig. 6.
4. If welds did not pull buttons, failure was at interface.

Projection Welding of Unequal Thickness

In Thickness Ratio of 1:1 through 3:1

Projections can be placed in either material thickness, although the welding process will be less sensitive if projections are in the thicker sheet. The projection size is determined by the thinner sheet. As the thickness ratio increases, the weld current and weld time are increased beyond the equal thickness ratio values to preserve adequate penetration into the thicker sheet. This added energy causes the nugget diameter to increase as illustrated in Fig. 11. The larger nuggets have more shear strength, and the results of making two projection welds simultaneously are tabulated in Table 7.

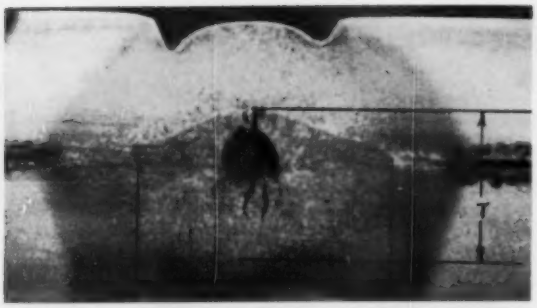


Fig. 9a—Two pieces of 0.245 in. thick LC steel using a standard projection. The resulting nugget is 0.470 in. in diam and 0.250-in. thick. The tensile shear strength was 15,500 lb at 0.015-in. sheet separation

Fig. 9b—Same as (a) except using a recessed projection (See Table). The nugget size is 0.440 in. in diam and 0.260-in. thick. The tensile shear strength was 13,500 lb at 0.00 in. sheet separation

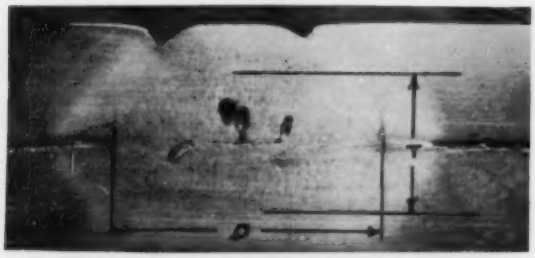


Fig. 9c—Two pieces of 0.179 in. thick LC steel using a standard projection. The resulting nugget is 0.400 in. in diam and 0.150-in. thickness. The tensile shear strength was 9500 lb at 0.009-in. sheet separation

Fig. 9d—Same as (c) except using a recessed projection. The nugget size is 0.350 in. in diam and 0.120 in. thick. The tensile shear strength was 8800 lb at zero sheet separation

Fig. 9—Comparison of setdown using standard and recessed projections

Table 7—Test Results for Unequal Thickness Welds (Welding Two Projections in 0.035 Material Simultaneously)

Gage	Weld time, cycles	Electrode force, lb	Welding current, amp	Average tensile shear, 2 welds, lb	Tensile shear for each projection calculated, lb	Variation[a]
0.035 to 0.035	6	300	9,800	1188	594	0.05
0.035 to 0.045	8	300	10,100	1238	619	0.10
0.035 to 0.060	14	300	10,500	1625	812	0.06
0.035 to 0.090	21	300	11,200	1766	883	0.13
0.035 to 0.120	30	300	11,500	1668	834	0.17
0.035 to 0.188	50	300	11,700	1889	944	0.06

[a] Variation = maximum shear-minimum shear/average shear.

NOTES:
1. The weld schedules were established by taking the base values from Schedule B, Table 2. The weld current magnitude was increased by factor f_c and weld time by factor f_t from Fig. 12.
2. Projections of 0.110 base diameter and 0.030 height always in the 0.035 material on 0.50-in. centers.
3. The average shear strength was determined by testing 5 welds.
4. The metallurgical structure of welds is shown in Fig. 11.
5. All welds pull 2 buttons.

In shear tests, metal tore around the projections leaving buttons on the thicker sheets. The welds were made on a bench welder (1000 lb maximum electrode force) with rapid follow-up characteristics. The approximate increase in weld current and weld time is determined from Fig. 12. An example illustrates the procedure.

Problem: Determine the current and time required to projection weld, using two projections, one piece of 0.035 in. thickness (21 gage) to one piece of 0.060 in. thickness (16 gage).

Step 1: Select the proper welding schedule from Table 2. Schedule B is recommended for two projections. The welding current is 5100 amp per projection. The weld time is 6 cycles. The electrode force is 150 lb per projection.

Step 2: The thickness ratio is 0.060 in. divided by 0.035 or 1.72 to 1. Select the current factor (f_c) and the time factor (f_t) from Fig. 12.

$$f_c = 1.07 \text{ and } f_t = 2.2$$

The corrected current is 5100 (1.07) = 5400 amp. The corrected time is 6 (2.2) = 13.2; use 14 cycles.

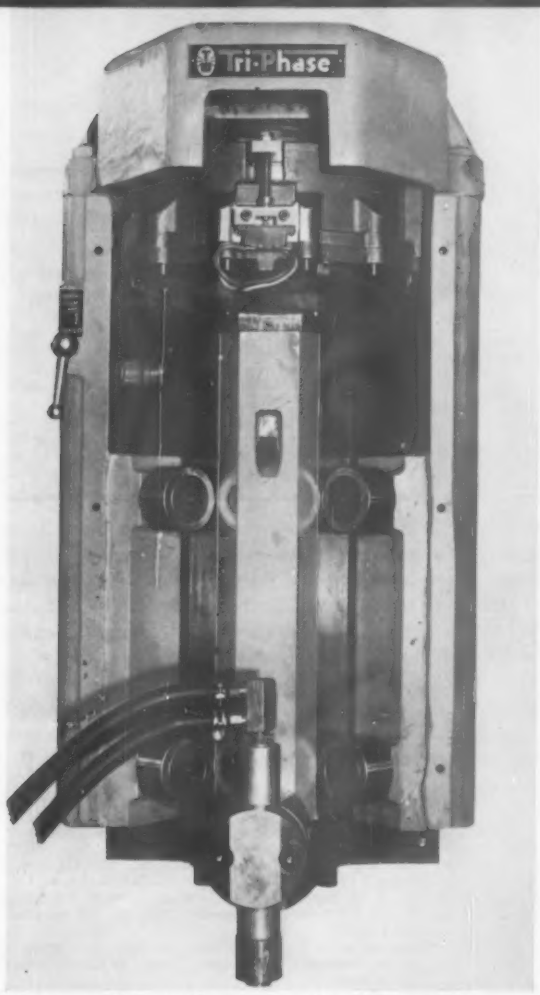


Fig. 10—Use of a double pressure airlock and roller ram construction eliminates the effect of cylinder friction

For two projections, the weld current is 2 (5400) = 10,800 amp and the weld force is 150 (2) = 300 lb. The weld time is 14 cycles. These are the values illustrated in Table 7 within the expected accuracy that a general correction curve such as Fig. 12 would produce. Deviations between calculated and measured values may vary ± 10%.

Thickness Ratio of 3:1 through 6:1

Projections are usually formed in the thinner sheet because of the forming problem involved if placed in the thicker sheet. Additional problems may appear in the welding process. Surface burning at the electrode-weldment contact surfaces can be minimized by using an electrode made from RWMA Class 1 or 2 alloy, rather than the previously recommended Class 3. The weldment surface must be clean or free from foreign material as this contributes to surface marking.

The equipment follow-up characteristic may have to be improved by using spring-loaded electrodes or equivalent. Up-slope control may compensate for slow follow-up but not as effectively as on equal thicknesses. An uneven heat balance exists, and the weld current cannot be made too low initially without causing projection collapse without welding. The tendency for unequal nugget size greatly increases with increased thickness ratio. This can be

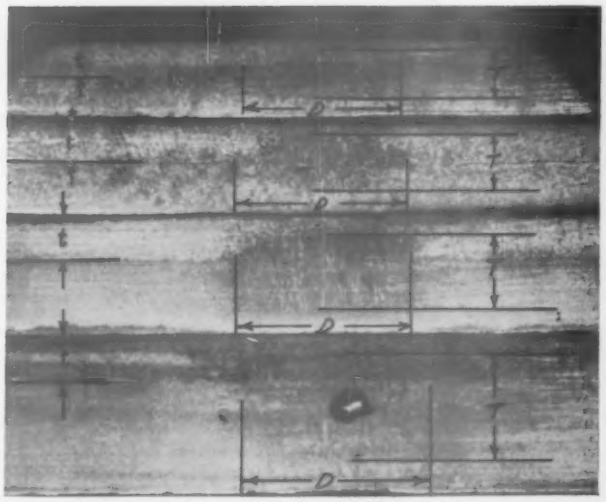


Fig. 11a—0.035 to 0.035 in., D = 0.090 in., T = 0.030 in.
Fig. 11b—0.035 to 0.045 in.; D = 0.130 in., T = 0.040 in.
Fig. 11c—0.035 to 0.060 in.; D = 0.150 in., T = 0.055 in.
Fig. 11d—0.035 to 0.090 in.; D = 0.180 in., T = 0.080 in.

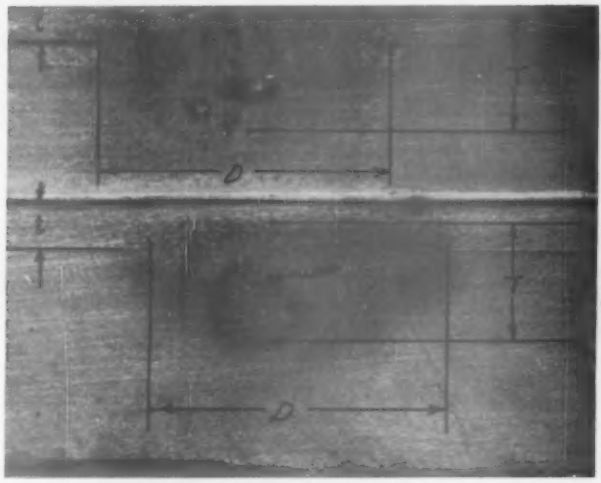


Fig. 11e—0.035 to 0.120 in.; D = 0.210 in., T = 0.090 in.
Fig. 11f—0.035 to 0.188 in.; D = 0.240 in., T = 0.090 in.

Fig. 11—Projection welding of unequal thickness—only one weld shown. (Note displacement of nugget and its increase in diameter as thickness ratio increases)

partially compensated for by the use of localized surface electrodes promoting better current and force distribution.

It must be realized that general information becomes of questionable accuracy when the thickness ratio exceeds 3 to 1. The actual joint design and the equipment, itself, have a pronounced bearing on the welding procedure and results. An experimental setup must be made using actual parts and equipment to determine weld quality. The starting point would be the previously outlined procedure.

Conclusion

The data contained herein will assist the welding engineer in the selection and operation of projection welding equipment. The equipment characteristics

Table 8—Test Results Welding Three Projections Simultaneously

Thickness, in.	Schedule from Table 2	Weld time, cycles	Electrode force total, lb	Welding current total, amp	Tensile shear total, lb	Tensile shear average per projection, lb	Variation[a]	—Projection size— Base diameter, in.	Height, in.	Projection spacing in.[b]
0.035	B[c,d]	6	450	15,200	1510	503	0.16	0.110	0.030	0.50
	C[e]	11	375	11,400	1418	472	0.19	0.110	0.030	0.50
0.062	A[f]	10	1650	20,000	4049	1350	0.18	0.150	0.042	0.75
	C[g]	24	1000	16,300	4224	1408	0.10	0.150	0.042	0.75
0.091	A[h]	16	3060	31,700	8863	2945	0.09	0.210	0.050	1.00
	C[i]	42	1830	21,500	8115	2705	0.21	0.210	0.050	1.00

[a] Variation = maximum shear-minimum shear/average shear.
[b] The projection pattern was an equilateral triangle whose side was equal to the indicated spacing.
[c] Schedule A was investigated but produced excessive expulsion when welding three projections.
[d] All welds pulled 3 buttons.
[e] Nine welds pulled 3 buttons, 1 weld 2 buttons, 4 welds 1 button, 1 weld sheared.
[f] All welds pulled 3 buttons.
[g] Twelve welds pulled 3 buttons, 3 welds 2 buttons.
[h] Eight welds pulled 3 buttons, 1 weld 2 buttons, 1 weld 1 button, 5 welds sheared.
[i] One weld pulled 3 buttons, 1 weld 2 buttons, 13 welds sheared.
NOTE: The average shear strength was determined by testing 15 welds.

have a major bearing on the resultant projection welds. Consequently an average tabulation of recommended data must necessarily be modified dependent on the equipment. The work outlined in this paper was performed on modern equipment employing roller bearing rams and airlocks to reduce the effect of ram and cylinder friction. The equipment was adjusted to control the impact force, so often neglected because it cannot be easily measured or listed.

The recommendations are based on more information than the presented results. Projection welding machines sent through the test floor have been adjusted in accordance with the schedules which thus have been verified by observing the results. These tests have proved both the usefulness of these schedules and also the impossibility of using the same welding technique on all joint designs. The distribution pattern of the projections and the fit-up of the component parts combine to require individual analysis of each joint and deviation from the recommended average set-up values.

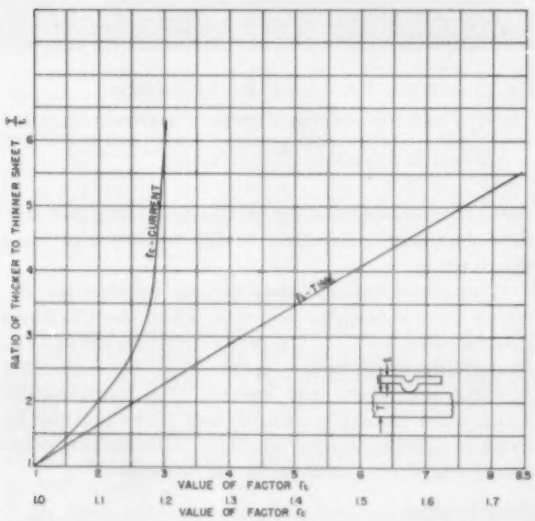


Fig. 12—Correction factors for weld time and current in Table 2 when projection welding unequal thicknesses using electrode force for thinner sheet

References

1. W. F. Hess and W. J. Childs, "A Study of Projection Welding," THE WELDING JOURNAL, **26**, (12), Research Suppl., 712-s to 723-s (1947).
2. W. F. Hess, W. J. Childs, and R. F. Underhill, Jr., "Further Studies in Projection Welding," **28** (1), Research Suppl., 15-s to 23-s (1949).
3. E. F. Nippes, J. M. Gerken, and J. G. Maciora, "The Projection Welding of 0.010 and 0.020 in. Steel Sheet," *Ibid.*, **29** (9), Research Suppl., 441-s to 449-s (1950).
4. E. F. Nippes and John Gerken, "Projection Welding of Steel in Heavy Gages and in Dissimilar Thicknesses," *Ibid.*, **31** (3) "Research Suppl., 113-s to 125-s (1952).
5. R. Bushell, "A Survey of the Projection Welding Processes," Sheet Metal Industries, September 1944, pp. 1977–1986.

APPENDIX A

The welding equipment must be adjusted so that the impact force as the electrodes close does not seriously deform the projections. If it is assumed that the ram acceleration is constant, then velocity $= \sqrt{2as}$ in which a is the acceleration and s is the distance moved. The velocity increases as s increases.

The momentum at impact or as the electrodes close equals MV in which M is the mass of moving system and V is the final velocity. The momentum must be dissipated at impact.

The impact Ft equals momentum MV in which F equals impact force and t equals time it is applied. t will vary with the resistance of the parts and equipment. Generally F will be greatest when the momentum is greatest.

The resisting force per projection will be F/n in which n is the number of projections. There is a maximum value for F/n for any particular gage and projection shape. The larger the number of projections being welded, the larger the value of F can be without exceeding the maximum value of F/n. Thus as the number of projections increase the operating speed of the ram can be increased without excessive impact.

Interior of cold-wall high-temperature internal-element vacuum furnace showing both front and rear doors open

Brazing of Sandwich Structures of **Columbium Alloys**

as carried at 4000° F in a "cold-wall" furnace results in a ductile and strong joint at 3000° F

BY M. M. SCHWARTZ

Man's advance into space and the effectiveness of his missiles are paced by his progress in high-temperature structures technology. Virtually every future design will involve operating environments with temperatures far in excess of the capabilities of current structures and materials.

The success of every prime contractor, subcontractor and vendor will depend heavily on his knowledge of, and ability to work with, upcoming high-temperature materials and structures. Important among these are the refractory metals, with good structural strength in the 3000° to 4500° F range. This compares with a current limit of 1800° F, absolute future limit of 1900° F, for stainless steels and the nickel/cobalt-base alloys.

Manned spacecraft are being designed for repeated flights from earth and back and will have to maintain their structural integrity and aerodynamic geometry under severe stresses at temperatures ranging to over 3000° F often cycled at rapid rates.

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The chemical character of the various environments will extend from the extremes of oxidizing atmospheres to reducing ones and, in the case of rocket motor exhausts, will include a great variety of reactive and erosive particles. Structural skins of spacecraft will be variously exposed to high thermal shock, mechanical fatigue, chemical attack, ultraviolet, nuclear, and cosmic radiation, and both compressive and tensile stresses to the limit of material tolerances.

Of the several approaches to these problems involving materials such as plastics, metals, ceramics, plastic-metal-ceramic composites and inorganic polymers; one of the most challenging and potentially one of the most rewarding is current research in refractory metals.

Refractory Materials and Brazing

The refractory metals are just emerging as important practical materials for high-temperature applications. Almost without exception, however, practically every high-temperature application involves a heavy measure of development as well as straight-forward production. Above 2500° F, for

example, there are no proper criteria for design specifications. There are no adequate testing procedures and facilities for developing such criteria. As often as not, a new operational requirement necessitates a whole new look at both materials and fabrication techniques.

Materials used for constructing various types of re-entry vehicles such as lifting-body re-entry rockets and glide re-entry rockets are subjected to temperatures in excess of 2500° F. There has developed, therefore, a need for high-temperature metals capable of withstanding these severe temperatures. Refractory metals like columbium (niobium), tantalum, molybdenum, tungsten and their alloys have been comtemplated for use in the critical portions of such structures, but no satisfactory means of brazing these refractory metals for service above 2500° F has been discovered.

The main difficulties in brazing refractory metals are not process problems. Suitable processes exist, although with some equipment limitations, and do not pose basic limits to what can be done in refractory metal brazing. The basic limits to refractory metal brazing are posed by three metallurgical problems. (1) recrystallization and ductile-brittle transition temperature, (2) the formation of intermetallics between refractory metal and brazing filler metals and (3) the relative weakness of brazing filler materials at elevated temperatures.

Metallurgical Problems

Recrystallization and Ductile-brittle Transition Temperature

The determinental effects of recyrstallization occurring with the refractory metals are not serious in a metallic heat-shield application since this component is not a load-bearing structure of the vehicle. The ductile-brittle transition temperature is, however, of vital concern in fabrication. Here, with the advent of commercially available refractory alloys, the brittle transition temperatures are constantly being lowered below room temperature. The transition from ductile to brittle behavior is very pronounced in the family of body-centered cubic metals in which family the refractories fall.

Formation of Intermetallics

The formation of intermetallics between refractory metals, their alloys and brazing filler metals is harmful due to the brittleness of the intermetallics which may fracture at relatively low loads when the joint is stressed. Just as recrystallization may occur either during brazing or during elevated temperature service, intermetallics will form under either condition.

Relative Weakness of Filler Materials

The relative weakness of filler materials at elevated temperature poses a basic limitation for the use of brazed refractory metal assemblies. Most nickel-base filler materials used at elevated temperatures melt in the range 1800–2100° F, where the

Fig. 1—Metal radiative heat shield made from columbium-base alloy with 33% Ta and 0.7% Zr and brazed at 3300° F. Structure consists of two formed cups with a honeycomb filling

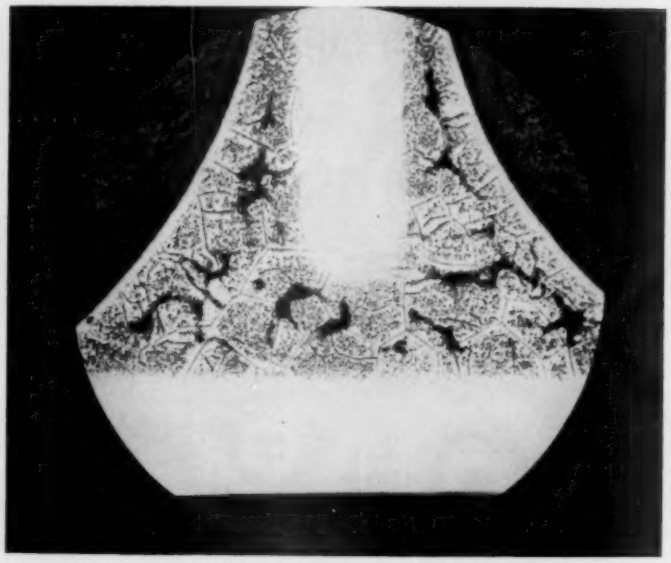


Fig. 2—Photomicrograph of a brazed joint using pure titanium as the brazing material. Note that parent metal (columbium base alloy with 33% Ta and 0.7% Zr) shows no signs of erosion; good wetting action is apparent

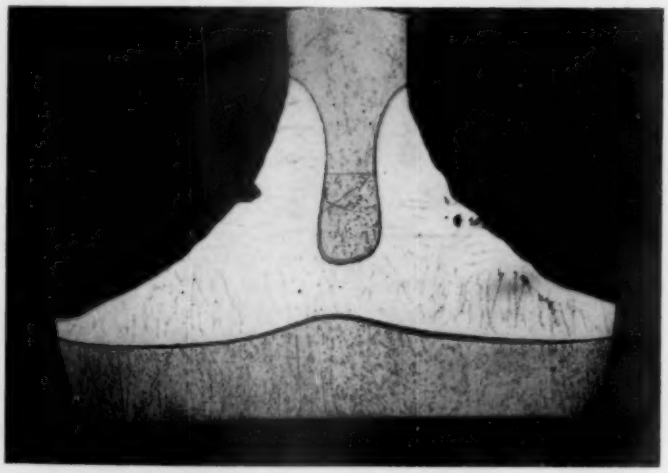


Fig. 3—A photomicrograph of a 90% platinum – 10% rhodium brazed joint showing the excessive erosion of the parent metal (columbium-base alloy with 33% Ta and 0.7% Zr)

superior elevated temperature strength of refractory metals such as columbium begins to manifest itself. Special high melting point filler materials for refractory metals are clearly indicated—provided, of course, that they do not cause refractory metal recrystallization or form intermetallics with the metal. These are difficult requirements, and no one material today completely satisfies all of them.

Test Program

General Approach

A suitable brazing material must possess structural strength at temperatures up to about 3000° F. In addition it must form a ductile joint which will not become embrittled by high-temperature service. Noble metal base alloys have been previously suggested; examples are: 70 palladium – 30 copper, 70 palladium – 30 nickel, 84 nickel – 16 titanium and 52 columbium – 48 nickel. However, these alloys form brittle compounds with the parent metals, thereby seriously reducing the strength of the brazed joint.

Metal radiative shield sandwich type structures such as those illustrated in Fig. 1 and capable of withstanding 3000° F for short periods of time were a goal of a research and development structures program. To meet the necessary requirements, a program was initiated to evaluate the brazing of refractory metals such as molybdenum or columbium Emphasis was placed on selecting brazing alloys for columbium rather than molybdenum, because columbium has better fabricability characteristics and is more resistant to oxidation than molybdenum. The strength of columbium is lower than molybdenum; however, there are alloys of columbium namely 10% titanium – 10% molybdenum and 33% tantalum – 0.7% zirconium which are now commercially available and approach the strength of molybdenum.

Another factor in the selection of columbium is that embrittlement does not accompany recrystallization as in the case of molybdenum. This, however, is not true for some columbium alloys, so it is advisable that the selection of a particular columbium alloy be made carefully. Although columbium is more oxidation resistant than molybdenum, a protective coating must be employed as the proposed service temperature. Columbium and its alloys are more affected than molybdenum by diffusion of interstitials (chiefly oxygen) which severely embrittle the metal.

Although each metal has undersirable attributes, the design of the radiative shield was such that columbium offered less problems in fabricating the final product, a sandwich type structure capable of withstanding 3000° F.

Procedure

The first high-temperature brazing experiments were conducted in a cold wall 3500° F vacuum furnace whereby pure columbium joint specimens were brazed. At this time only two braze alloys were evaluated—namely, pure platinum and pure titanium. These specimens were brazed at 3300° F and microscopic examination indicated that pure titanium was far superior to platinum as a braze alloy. Initial studies indicated that platinum eroded the columbium base metal severely and also produced a very brittle joint. Titanium, however, alloyed slightly with the base metal and produced a ductile and strong joint.

After the initial brazing studies, a survey of possible brazing alloys for columbium and its alloys was conducted. As a result, several high-temperature brazing alloys were selected for evaluation:

Alloy	Brazing temperature, ° F
Palladium	2900
Platinum	3300
Titanium	3300
90% Platinum (Pt) – 10% Iridium (Ir)	3300
90% Platinum (Pt) – 10% Rhodium (Rh)	3450

The term "titanium" as used herein is titanium which proved on analysis to be commercially pure titanium with a yield strength at 0.2% offset of between about 40,000 to about 80,000 psi. Commercial titanium satisfying this requirement is designated A-40 and A-55. The melting point of A-40 and A-55 type titanium is about 3300 ± 25° F. Titanium, in addition to its metallurgical compatibility with the refractory metals, also possesses a comparable coefficient of expansion which further insures the soundness of the brazed joint—Fig. 2.

The base alloys of columbium were brazed with each of the above named brazing alloys. However, discussion here is mainly on the columbium alloy with 33% tantalum and 0.7% zirconium since most work was done with that alloy. In general, the results of these preliminary tests were very promising. Of the filler alloys selected for evaluation, only the 90 platinum – 10 rhodium alloy was deleted because it severely erodes the base metal and produces a very brittle joint—Fig. 3.

Titanium appeared to be the best brazing alloy for columbium and its alloys, because it produced a strong and yet ductile joint. However, titanium will dissolve the base metal to a slight degree to form a solid-solution-type alloy with columbium. The solution of the base metal probably can be controlled by more closely pinpointing the brazing temperature. Palladium, platinum and 90% platinum – 10% iridium tend to dissolve the parent material to an extent. One drawback, however, is that these braze alloys produce relatively brittle joints. Therefore, at the present time pure titanium appears to be the optimum braze alloy for columbium with 33% tantalum and 0.7% zirconium.

Test Furnace

Construction

A recently installed cold-wall high-temperature internal-element vacuum furnace was used for this

Fig. 4—These tools have been run through the 3300° F cycle nine times and show no evidence of distortion

brazing—see lead photograph. To the best of our knowledge, the furnace is the largest and only one of its kind in the country today. This resistance furnace is designed for sintering, brazing, heat treating and annealing at 4500° F operating temperatures and pressure in the 0.1 micron range. No nonmetallic refractories are used inside the vacuum chamber (with the exception of thermocouple and power feed through insulators, which are shielded and remain cold.) The use of metal heat-shields to control heat loss allows operation at high temperatures and low pressures.

The furnace heater interior dimensions are 12 x 12 x 12 in. The operating temperature can be 4000° F for periods of 1 hr while the maximum operating temperature is 4500° F for shorter periods of time. The service life of the heating elements is shortened considerably when the furnace is operated at 4500° F due to the recrystallization and grain growth of the heating elements. A vacuum pressure of 1 x 10^{-6} mm of mercury is also required. The power control is a saturable core reactor, while the temperature control is recorded with thermocouples.

An outstanding feature of the furnace is that the chamber opens on either side of the shell. This facilitates placement of the work charge and the maintenance of the elements and shields.

A most important consideration in any high-temperature vacuum "cold-wall" furnace is the design and construction of the resistance heating element. Conventional designs, which have been used are rod, wire or ribbon elements, most of which require refractory insulation that is exposed to the radiant heat. This insulation is used to electrically isolate the heating elements from each other and from the ground. Nonmetallic refractory insulation is not used in this furnace, since it will not withstand temperatures of 5000° F.

The heating elements are strips of tantalum located on all six sides of the working area. The heater strips are corrugated for strength and supported by shielded water-cooled copper posts. These elements operate on low voltages to prevent any possibility of arcing between elements or other furnace components. Furthermore, thermal expansion problems are alleviated by a unique serpentine design in the heating elements. The radiation losses from this type of element are less than with rod or ribbon elements as reflected heat from the work-charge passes between the ribbon and rod elements to the heat shields. Therefore, with the closely-spaced corrugation, serpentine-designed heating element radiation and conduction losses are held to a minimum. Distortion, which materially effects the element and is caused by inherent differential expansion, is practically non-existent with this new type element design.

The radiation shields are arranged in packs. Each package assembly consists of three tantalum and three molybdenum shields secured together with pins. These assemblies are mounted from the walls of the tank on brackets.

Power is brought to the heating element tabs by means of water-cooled copper bus bars to which the heating elements are bolted. An additional water-

cooled copper bus bar supports the heating elements at intervals to prevent excess distortion and growth.

Tungsten rods located at 4-in. centers extend through the bottom heat-shields and heating elements to support the work jig and the assembly. The total power input is 200 kw. The power input is divided equally on all six sides. Saturable core reactors control the voltage to the heating elements in each zone.

Temperature Measurement

The problem of measuring and recording reliable readings at temperatures of 4000° F is a difficult one. Extensive research in the measurement of high temperatures has been conducted with optical pyrometer methods as well as thermocouples. Tungsten-molybdenum and tungsten-iridium thermocouples are limited, because the tungsten-molybdenum combination has low thermal electromotive force and becomes brittle upon temperature cycling and because iridium is brittle to some extent and is very scarce.

The drawback when using optical methods such as a Rayotube or similar units for temperature indication is condensation. It is extremely difficult to prevent condensation from occurring on the sight glass, which is used for Rayotube viewing. A long water-cooled viewing tube can be used, and over a period of time the condensate caused by gas evolution from the charge will eventually darken the glass. Sight glass wipers cannot be used as it means an operator must continually clean the inside surface. If this has to be done, than the furnace might just as well be operated manually. Obviously, sight glass shields are out of the question since it is possible to have the Rayotube call for more heat when the charge is already up to the desired operating temperature.

Because of limitations described above, a decision was made to use a tungsten-rhenium thermocouple. Initially, the thermocouple insulators were thoria. However, recent tests have indicated that thoria becomes extremely conductive at approximately 2800° F; therefore, a sheathed tungsten-rhenium thermocouple is now being used. The sheath material is tantalum while the insulation material within the sheath is beryllium oxide. Tungsten-rhenium thermocouples with beryllium oxide insulators have been evaluated and have performed satisfactorily.

Operating Requirements

The power supply of the unit is capable of delivering 242 kw. The furnace is capable of using 225 kw. To date, no more than 135 kw have been required to operate the furnace and its accessory equipment.

A minimum pressure of 40 psi and water temperature of 60–85° F is required to produce a flow of approximately 100 gpm when the furnace is operating at 4200° F.

The heating elements are made in sections; thus only those portions that are defective need be replaced. If the entire set of heating elements need replacing, approximately 16 man-hours are required to do the job. However, this operation cost should not occur very frequently, since 75 hr at 4000° F temperature and a minimum of 250 hr at 3500° F temperature can be expected.

Tooling

The tooling material for use at 3000° F is limited. Refractory metals and/or their alloys, ceramics, graphite, newly-developed carbides or borides, and refractory coated graphite are the only materials available since the furnace temperatures are beyond the limits of commonly used tooling materials of today—Fig. 4.

Of the aforementioned materials, ceramics capable of withstanding 3000° F such as, alumina, zirconia and beryllia cannot be used in a vacuum atmosphere due to contamination, reaction with refractory metals and thermal expansion and contraction. Graphite is another bad actor, al-

Fig. 5—Radiation shield assembled in brazing tool

Table 1—Maximum Temperatures Beyond which Ceramics React with Refractory Metals

Material[a]	Molybdenum	Tungsten	Tantalum	Columbium
Graphite	Strong carbide formation beyond 1200° C	Strong carbide formation beyond 1400° C	Strong carbide formation beyond 1000° C	Strong carbide formation beyond 1000° C
Al_2O_3	Up to 1900° C	Up to 1900° C	Up to 1900° C	Up to 1900° C
BeO	Up to 1900° C	Up to 2000° C[b]	Up to 1600° C	Up to 1600° C
MgO	Up to 1800° C	Up to 2000° C[b] (strong magnesia evaporation)	Up to 1800° C	Up to 1800° C
ZrO_2	Up to 1900° C[b] (strong molybdenum evaporation)	Up to 1600° C[b]	Up to 1600° C	Up to 1600° C
ThO_2	Up to 1900° C[b]	Up to 2200° C[b]	Up to 1900° C	Up to 1900° C
Sillimanite	Up to about 1700° C	Up to about 1700° C	Up to about 1600° C	Up to about 1600° C
Firebrick	Up to about 1200° C	Up to about 1200° C	Up to about 1200° C	Up to about 1200° C
Magnesite brick	Up to about 1600° C	Up to about 1600° C	Up to about 1500° C	Up to about 1500° C

[a] While these materials will withstand the desired brazing temperatures, they cannot be used for tooling since they cause continuation of refractory metals.
[b] In vacuum of 10^{-4} mm; under protective gas about 100–200° C lower temperatures.

though it does have excellent dimensional stability. As shown by Table 1, however, it embrittles the refractory metals which are the heating element materials. The newly-developed carbides and borides (zirconium boride, zirconium carbide, titanium carbide) are still in the developmental stages and, therefore, are a little way off from used. This leaves only the refractory metals and their alloys. Here the particular metal or alloy used will depend entirely on the assembly to be built. For example, the metal radiation shield in Fig. 5 was composed of the columbium base alloy containing 33% tantalum and 0.7% zirconium. Presently, the thermal expansion rates of this alloy have not been published and, due to the unavailability of this alloy in 0.250 gage thicknesses, pure columbium was used as the tooling material.

It was felt that the coefficient of thermal expansion of pure columbium was close enough to that of the alloy under discussion. Therefore, it was used. The components after brazing at 3300° F were held within ±0.010 flat tolerance. Thus, it appears that tooling material for 3000° F temperature brazing can be designed and built with refractory metals. However, the cost of the basic tooling material and the subsequent manufacturing operations to utilize it are very high.

Figure 6 depicts a series of tests conducted on lap shear specimens made from the columbium-base alloy with 33% tantalum and 0.7% zirconium—Fig. 7. The data indicate that the brazed joint (titanium was the braze alloy) had comparable shear strength at 3000° F (480 psi) compared to the parent metal.

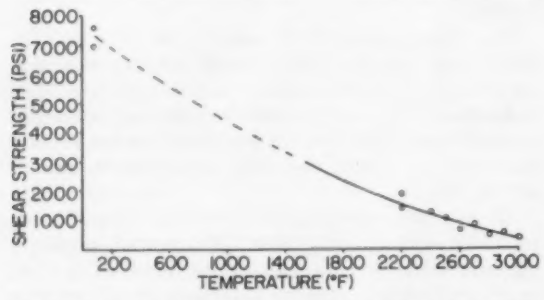
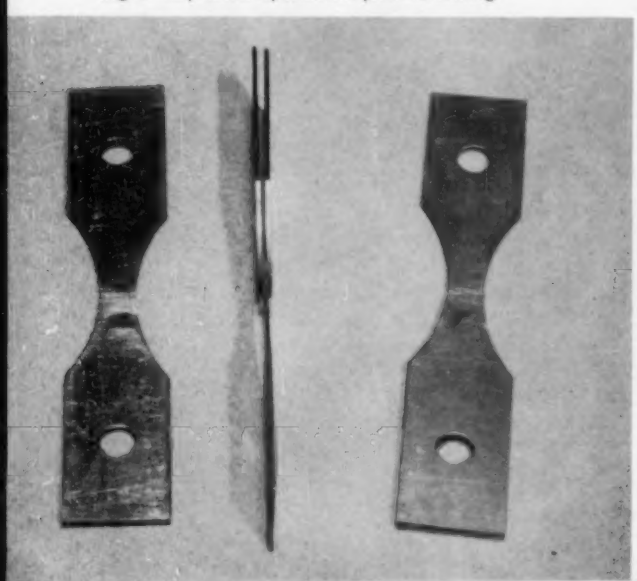


Fig. 6—Shear strength of columbium-base alloy (with 33% Ta and 0.7% Zr) brazed joints from room temperature to 3000° F. (0.032-in. thick material, double lap shear, 3300 F. braze temperature, and approx. 0.08 sq. in. braze lap area—brazed with titanium filler)

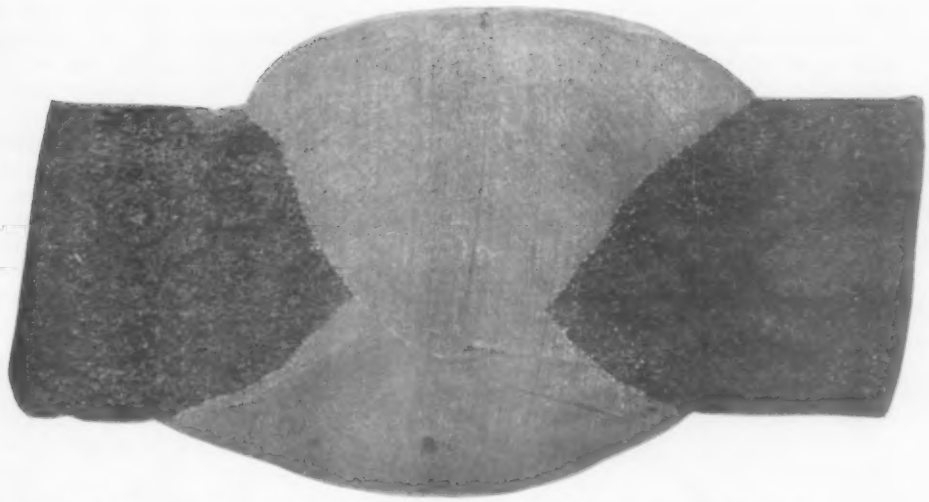
Fig. 7—Lap shear specimens prior to testing



Conclusion

With the advent of furnaces that can attain 4000° F temperatures in a controlled vacuum atmosphere and with the development of brazing alloys that produce ductile joints of strength equal to the parent metal, refractory metal can be used for fabricating the required components of missiles or space vehicles that will operate in what are to us abnormal environments.

While the cost of fabricating these exotic materials today seems high, the important thing is that a process has been developed. By the time space vehicles are commonplace, these costs will be in line with the over-all price of the vehicle.



A deeply etched weld shows that the weld metal itself, because of its method of deposit, is very much more sound than the steel immediately adjacent to it and is without many difficulties which are present in the parent metal

A pioneer in the field of welding argues against over-welding and for a limited degree of porosity in

Role of the Engineer in Designing for **Carbon-Steel** Structures

BY J. F. LINCOLN

The only commercial method which can be used for joining metals that will give full strength to the junction is welding. In spite of this fact, welding is not used because it is under continual suspicion, while any other method of joining metals such as riveting or bolting, which cannot possibly give full strength to the junction, is accepted without question. The reason for this is not hard to find since very few engineers are fully informed as to the proper use of welding.

During the last war there were a number of ships which were welded and broke in two. In all cases the break occurred not in the weld but only in the plate itself, yet welding was held under suspicion because the ship broke and the ship was welded. The reason that these failures occurred was not because of welding but because a welded structure is rigid. It does not have the ability to adjust to the changing stresses which will be put on it as would be true of a riveted or bolted joint which allows the members to slip to any extent that is necessary to adjust to the stresses that occur in the use of the structure.

The same problem of rigid failure is present in gray iron castings. In those cases the engineer merely strengthens the section which breaks because of the shrinkage stresses and accepts the problem without question. It is only in welding where this same problem is present that the engineer does not accept his responsibility of proper design.

J. F. LINCOLN is Chairman of the Board, Lincoln Electric Co., Cleveland, Ohio.

Problem of Stresses

There is no doubt that there are problems in the use of welding. It is different from what has been used. There is not only the problem of the rigid structure and the shrinkage stresses that will come into it but there is also the matter of the stresses in the deposited metal when it cools from the molten state it is in when the weld is made. Very great stresses are put on this metal as it cools. If there are no outside restraints the cooling takes place generally without difficulty and without cracking. That is particularly true of mild steel. It is possible to have a structure which will not allow the shrinkage to adjust itself quickly enough, under which conditions it is possible to have cracks. Particularly would that be true in high strength materials which would not allow the same stretch to be absorbed in the structure as would be true of mild steel.

Because of the suspicion which has been put on welding, many engineers increase the strength of the weld. Over-welding is one method which is common. The elimination of porosity is another one which is frequently used. When it is remembered that the tensile strength of the deposited weld metal is always higher than the tensile strength of the metal joined, it is obvious that over-welding is complete waste and also eliminates the possibility of adjustment of stresses in the weld that would be present when over-welding is not done.

Porosity as Insurance

The presence of the porosity is of great help in eliminating the possible cracking of the weld and the joined plates because of its ability to stretch to a greater extent than a solid weld would stretch. It has been proved that porosity up to 7% of the volume of weld metal does not interfere with the strength of a weld or with its ductility. Seven percent is much more than would be present commercially in any weld. The added insurance that the porosity gives would also materially reduce the possibility of cracks in the weld itself. Porosity is an insurance, not a defect.

Any welded structure will adjust to shrinkage stresses in it very rapidly so that cracking because of its rigidity will become less and less possible. In a comparatively short time the stresses are adjusted so that they disappear shortly after the weld is made.

It is well also to remember that the factor of safety which is used in all structures which are made of steel is at least four, which means that the stresses which would be present when the structure is used would be less than 20,000 psi. This is a small fraction of the ultimate strength or the elastic limit of either the weld or the material itself. It is also well to remember that any structure which is stressed up to even its elastic limit would have distortion and because of that distortion would be useless. Therefore, in actual service we deal with stresses which are a very small fraction of the tested strength of the material used. This is not only true of the structural material itself, but to a greater extent of the weld metal.

The material which goes into the weld itself is very much superior to the parent metal in the structure. Any weld which is deep etched will illustrate this fact completely. The reason is that the metal going into the weld is better than the parent metal. This is true not only because of its more careful selection but also because it is more homogeneous, as is shown by a deep etch.

Challenge to Engineers

It is necessary that our engineers use these facts in designing of welded structures so that the available economies which are tremendous will be obtained. At the present time a very large proportion of structures which should be welded, such as buildings, bridges and weldments of various kinds are not welded. This is because of the suspicion that has been built up in the minds of engineers generally resulting from their lack of knowledge. This suspicion has also resulted in tests which have very little basis in fact. The engineer has failed to take the forward steps which are obvious that welding gives to the economy compared to the old-fashioned designs of riveted and bolted structures.

When it is remembered that there are no tests put on a welded joint which a riveted or bolted joint could pass and there are no tests put on a welded joint which bear any relationship to the stresses that it is actually going to be subjected to in use, we can see how very far from reality we have strayed.

When the engineer accepts his responsibility to the economy in properly designing and using welding, he will save the economy billions of dollars. He also will produce better structures than we now have.

Memo to Authors . . .

An "Invitation to Authors" will appear in the May issue of the Welding Journal for the use of those considering the presentation of papers at the 43rd Annual Meeting of the American Welding Society to be held in Cleveland, Ohio, Apr. 9–13, 1962.

Practical Welder and Designer

Fig. 1—This casting was repaired for Whitestone Hospital, on the same day it broke, enabling the hospital to have its X-ray machine restored to service in time for emergency service on a major holiday weekend

Fig. 2—The repaired casting, ready for a new coat of black paint. The crack apparently began in an area of stress concentration where the two arms of the cross had been fusion welded together. To avoid aggravating this problem, the repair was done with minimum heat input through use of the "QuenchWeld" process

Emergency Repair of Hospital X-Ray Equipment

A recent emergency repair of X-ray equipment for a New York hospital served as a dramatic example of the speed with which cast iron welding can be accomplished using the appropriate process. Whitestone Hospital, in the Whitestone section of New York City, broke the casting assembly which rides the extension rail and supports the tube of its large diagnostic X-ray machine. The unit was useless without the casting. The accident occurred on the Friday preceding a major three-day holiday, a period when accident possibilities with consequent emergency need for X-ray could be expected to be higher than usual.

On short notice no commercial welding shop could be found to undertake the repair, and no new part could be obtained in time for the weekend. The hospital turned to Eutectic Welding Alloys

Based on a story from Eutectic Welding Alloys Corp. Flushing, N. Y.

Fig. 3—Pencil points out the repair area on the casting, back in service at the hospital. Casting rides horizontal rail, supports vertical arm on which X-ray tube is mounted. Machine could not be used until casting was repaired

Corp. in nearby Flushing, early on Friday afternoon. Eutectic, while a manufacturer of welding products rather than a welding production shop, has laboratory and training facilities where welding can be done. Members of its laboratory staff agreed to remain as necessary to make emergency repair, and the hospital promptly dispatched a truck with the broken casting.

Upon examination, the part was found to consist of two cast-iron cylinders, with walls approximately 1/2 in. thick, welded together at right angles to form a cross. Fusion welding in original manufacture had created stress concentration in the area of the weld. The crack had started at the weld and continued across one of the cylinders. Additional high heat input, it was felt, would only start new cracks at the weld, breaking off more pieces. Therefore it was decided to use a recently-developed process, based upon Eutectic's "QuenchTrode" 24 electrode which makes a deposit that can be water-quenched without cracking. Use of the quenching step not only minimized heat spread from the weld, but also speeded the repair process since it eliminated the usual wait for air-cooling between welding passes.

Using this process, the repair was completed within an hour, less than the time required for reassembly at the hospital. The machine was thus readied for duty on the evening of the same day, and due to the quick repair was not out of service during any part of the holiday weekend.

Arc-Welded Girders in Rail Bridge

BY H. S. DEWDNEY AND C. L. STOCKER

Unusual in design, attractive in appearance and economical in terms of material usage, construction and maintenance costs is a capsule description of a 207-ft single-track railroad bridge spanning the Victorville-Barstow Freeway in California. Set at about a 54 deg skew angle, the bridge has four all arc-welded main girders, two on each side, 24 ft apart, each weighing 35 tons and measuring approximately 101 ft long and 10 ft deep. Piers carry the girder ends at center points.

The bridge floor is a series of parallel 21-in. WF beams, spaced on 2-ft centers and attached to the girder webs by five 7/8-in. high-strength bolts through 4-in. T-section clips 18 in. long, welded to the webs just above the lower girder flanges. Low-alloy high-tensile steel strips 30 in. wide and 1/2 in. thick are lap welded together and laid transverse across this strong structural floor to produce a solid bridge deck.

Track rails and ties are set into a protective layer of bituminous and stone ballast previously laid on this "pan." This places the track at the lowest level possible and avoids spilling loose limestone rock onto the highway below from the large 135 ton side-dump ore cars that use the bridge.

Even with this depressed track design, highway officials deemed it advisable to erect a 4-ft high steel railing along the top girder flanges for added highway protection. Figure 1, illustrating the completed bridge, shows this detail, as well as the clean, unbroken lines of the fascia sides of the girders. Girder stiffeners are two longitudinal 7-in. wide and 5/8-in. plates fillet welded to the girder at points 2 ft from either flange. Bridge "low steel" clears the highway by 15 ft.

The bridge carries a 15-mile standard-gage feeder line of the Mojave Northern Railroad of Southwestern Portland Cement Co. over the Victorville-to-Barstow highway from a limestone quarry to a tie-in with the Santa Fe Railroad near Victorville. The structure is designated officially by the California Division of Highways as the North Victorville Underpass VIII-SBd-31-D.

Welded girders were selected because of their economy of construction and maintenance. Weight saving over comparable riveted construction was estimated to be about 20%. The bridge was designed for railway live loading approximately equal to a cooper E51 for girders and E53 for floor beams. Design, under supervision of R. S. Barker for the highway department bridge division, was in accordance with AREA and AWS specifications for welded highway and railway bridges.

On the inner webs of the girders, stiffeners or brackets of two types, one triangular and the other straight, are spaced about 6 ft apart—Fig. 2. These brackets, acting as stiffening and compression flanges, also take some transverse and lateral shear in their panels. High strength bolts, 7/8 in. in diam., connect the brackets to the floor beams. Initial tension developed in these connecting bolts carries the moment into the floor beams. Bolted connections of floor beams to the previously mentioned girder web clips were used in place of welding to

H. S. DEWDNEY is Chief Structural Engineer, Vinnell Steel, Irwindale, Calif.; C. L. STOCKER is District Engineer, The Lincoln Electric Co., Emeryville, Calif.

Fig. 1—Trim fascia lines show the arc welded steel design of the four 10-ft deep girders of this 207-ft depressed-track railroad bridge carrying an industrial rail line over a freeway

Fig. 2—One of the 101-ft girders as arc welded in Vinnell Steel shop. Transverse floor beams are bolted to the series of T-clips welded to the girder web

reduce fatigue effects.

Field splicing of girders by welding was not permitted under state specifications. The girders in Fig. 3 were shop fabricated complete by Vinnell Steel at Irwindale, Calif., and hauled to the site on special truck trailers. Vinnell Steel also handled erection details. Steel plate for the girders, structurals and low-alloy plate shown in Fig. 4 for the deck were supplied by Kaiser Steel.

Girder flanges are 22 in. wide, in three thicknesses —$1^1/_4$ in. at the ends, $1^3/_4$ in. intermediate and $2^1/_4$ in. at the center. Butt weld splices on these flanges and the $^5/_8$-in. thick web plates are double-vee beveled prior to welding. Flange splices had to be at least 6 in. from web splices, and both flange and web splices had to be at least 6 in. away from vertical stiffeners. The bottom girder flange could not be spliced within 15 ft of the span centerline.

From the design specifications issued by the bridge division of the California highway department, the following notes on welded girders outline welding requirements and are quoted verbatim for possible general interest:

"The relation between fillet weld size and the maximum thickness of material on which various sizes of fillet may be used shall be in accordance with Article 222 (b) of the AWS specifications dated 1956, with the following exceptions and unless otherwise noted: The size of fillet weld connecting girder webs to flanges over $2^1/_4$ in. thick shall not be greater than the thickness of the web. U-butt welds may be substituted for vee-type shown on the plans. J-butt welds may be substituted for bevel types shown on the plans. The methods of joint preparation shown on the plans are based on the use of manual shielded-arc welding. In the event that automatic or semi-automatic submerged-arc processes are used, the contractor may submit alternative methods of joint preparation for approval by the engineer. Shop plans shall indicate welding sequence and the type of steel to be used."

Fig. 3—Two of the four girders here are in place, supported by the center piers. Wide-flange floor beams are being bolted to clips. Only two longitudinal stiffeners are used on outer webs

Fig. 4—Over the floor beams goes a deck of welded low-alloy, high-tensile $^1/_2$-in. plate, lap welded. Reason for the depressed track is to avoid spillate of rock onto roadway from side-dump cars

The girders are carried on conventional concrete and steel abutments at their approach ends and on circular reinforced concrete piers at the center. Standard bearing details are provided on both abutments and on the center piers.

Expansion joints in the deck plate are placed near the center piers. Expansion at the abutments at floor beam bearings is provided for by placing slotted holes in individual sole plates and masonry plates (continuous over three bearings) at anchor bolt tie-downs.

The bridge is on a level grade to provide drainage under the ballast and off the steel floor deck. Thickness of the bituminous protective covering is varied. Giving due consideration to residual camber in the girders, this covering is applied to $3^1/_2$ in. thickness at the center piers and gradually thinned down to $1^1/_2$ in. at the abutments.

Society News

Annual Spring Meeting and Welding Show Potential Record Breaker

The New York scene for the AMERICAN WELDING SOCIETY this month promises to be spectacular. A record-breaking attendance figure of 18,000 is being projected for the Welding Show in the Coliseum. Latest reports on registrations indicate that more than 2000 AWS members and guests will be signed for the 42nd Annual Meeting technical sessions and social activities. Presstime reports from overseas indicate that 500 or more International Institute of Welding members will attend the first Annual Assembly to be held in the U. S.

Welding Show

All exhibit space for the April 18–20th Welding Show has been taken. A record number of welding engineers, supervisors, managers and distributors will ride the escalators to the Coliseum's second floor to examine more than $3 million in welding and related equipment presented by more than 115 exhibitors. Welding products manufacturers are having exhibits to show their latest developments—many with live demonstrations.

Technical Papers

World-wide research has brought many new developments in welding technology. Detailed information will be presented during 23 technical sessions at the Hotel Commodore the week of April 17th to 21st. More than 70 technical papers will be read, including 10 sponsored by the American Society of Electrical Engineers on electric welding, and nine sponsored by the IIW on European welding research.

Adams Lecture

The 1960 Adams Lecture on "Studies on Cracking and Transformation in Steels During Welding," will be presented by Henri P. Granjon, chef de service of the Institut International de la Soudure, Paris, France. Sponsored by the AWS, the lecture is presented each year by a prominent scientist or engineer, and customarily presents a new and distinctive development in the field of welding. This year's lecture is derived from work done by the IIW on weldability of steel.

National Welded Products Month

Governors and mayors all over the U. S. are issuing proclamations for April as National Welded Prod-

(Continued on p. 390)

AWS DIRECTORS-AT-LARGE

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CONSTRUCTION ON SCHEDULE

No matter how you look at it, the UEC building is progressing at a steady rate with an August completion in sight

UNITED ENGINEERING CENTER

Honor Sections

Section	Goal, %	Section	Goal, %
Oklahoma City	125	Louisville	100
Mahoning Valley	113	Madison-Beloit	100
Holston Valley	109	Maryland	100
Cincinnati	104	Michiana	100
Hartford	104	Nashville	100
Kansas City	102	New Hampshire	100
N. E. Tennessee	102	New Jersey	100
Puget Sound	102	N. Central Ohio	100
Tulsa	102	North Texas	100
Baton Rouge	101	Northern N. Y.	100
Colorado	101	Northwest	100
Detroit	101	Olean-Bradford	100
Niagara Frontier	101	Pascagoula	100
Providence	101	Philadelphia	100
Rochester	101	Richmond	100
San Diego	101	Salt Lake City	100
St. Louis	101	San Antonio	100
Birmingham	100	Sangamon Valley	100
Boston	100	Santa Clara Valley	100
Bridgeport	100	Syracuse	100
Chattanooga	100	Toledo	100
Dayton	100	Western Mass.	100
Eastern Illinois	100	Wichita	100
Iowa	100	Worcester	100
Long Beach	100		

Pledges Needed to Meet Goal

Section	Needed	Section	Needed
Mohawk Valley	100	York-Central Pa.	435
Tri-Cities	100	Fox Valley	450
Albuquerque	150	Saginaw Valley	460
Anthony Wayne	150	Lehigh Valley	475
Shreveport	195	Portland	485
Arizona	200	Indiana	490
Nebraska	200	Stark Central	495
Washington	200	Columbus	790
New York	218	Long Island	800
Carolina	245	Northwest	822
Northwestern Pa.	280	Milwaukee	927
J. A. K.	295	San Francisco	1008
Mobile	300	Cleveland	1155
Peoria	340	Houston (and Sabine)	1540
Susquehanna Valley	350	Chicago	1590
Western Michigan	350	Pittsburgh	2163
Iowa-Illinois	370	Los Angeles	2825
South Florida	370		
New Orleans	379		

REACHING OUR GOAL

One drop of water, then two drops and three soon made a cup and another until soon there was all the water that anyone could want. The same goes for United Engineering Center building fund contributions. Each drop of money in the coffer brings the total contributions nearer to our goal of $60,000.

Several new sections appear on the Honor Roll for having achieved 100% or better of their goal. However, AMERICAN WELDING SOCIETY pledges stand at 68% of goal.

(*Continued from page 388*)

ucts Month in an effort to gain public recognition of welding. AWS President R. D. Thomas, Jr., in a recent interview pointed out the importance of welding by saying: "The missiles which hurl satellites into orbit, the space program, the submarines which travel under the North Pole and which can launch missiles from the depth of the ocean, the aircraft which fly at fantastic and ever-increasing speeds, the nuclear reactors which bring power to underdeveloped areas, rely upon one basic process for their existence —welding."

Missile Symposium

The AWS Missiles and Rockets Welded Fabrication Committee will hold a symposium on April 19th at the Hotel Commodore to discuss aerospace welding fabrication problems. The symposium will consist of experts from major companies in the missiles and rockets field.

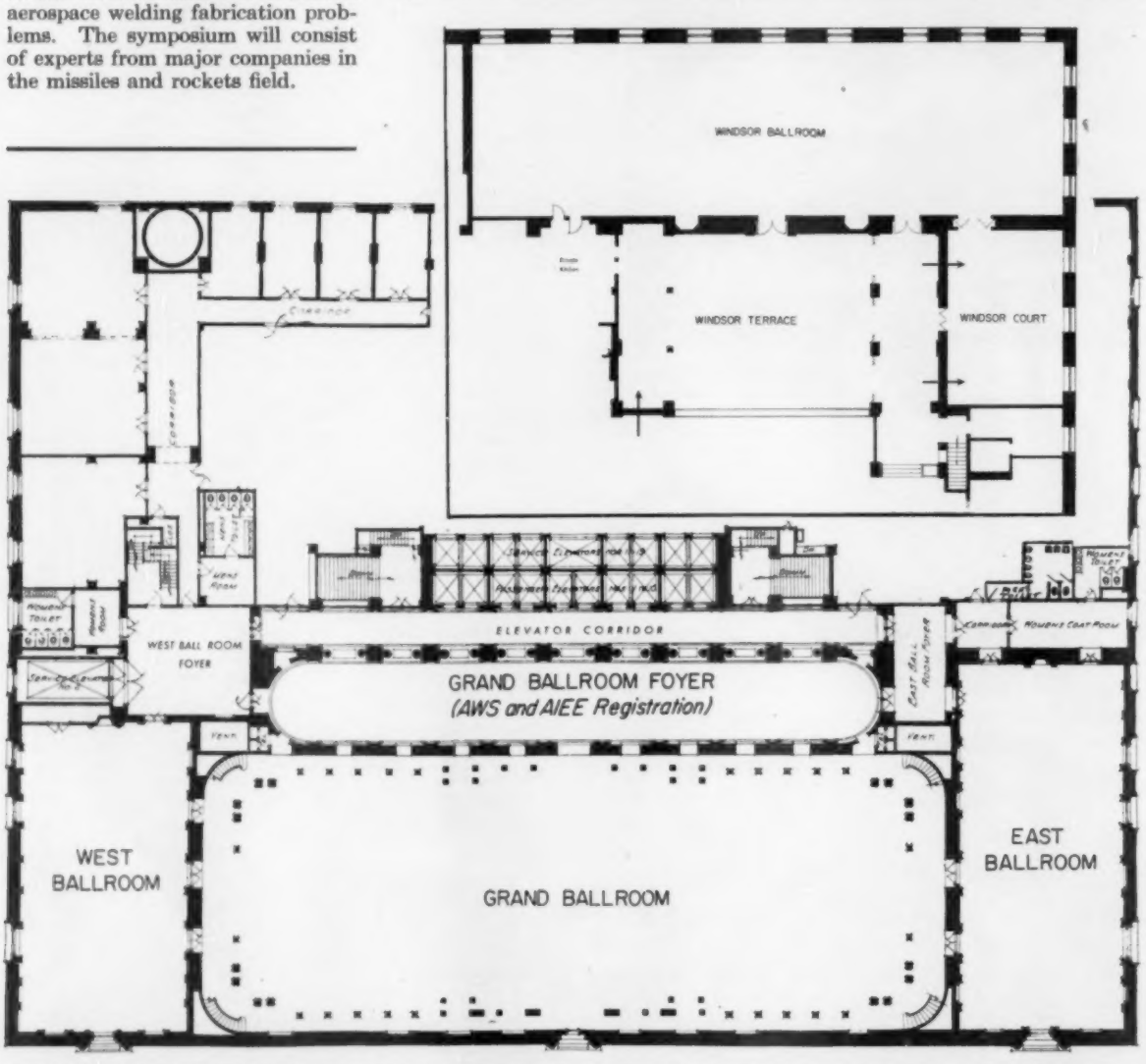
Ladies' Program

An exciting program is planned for the wives accompanying AWS members to New York. Special guided tours, a fashion show and plenty of shopping are a few of the activities. The ladies are invited to the President's Reception and Annual Banquet, which will be highlighted by a talk from an internationally-known speaker and professional entertainment.

Plant Tours

Several plant tours have been arranged during the AWS Annual Meeting week. AWS visitors will be able to see the Worthington Corp. plant in Harrison, N. J.; the Buick Oldsmobile Pontiac General Motors assembly plant in Linden, N. J.; the Linde Co. Development Lab., Newark, N. J.; the International Nickel Co. Research Lab. and Electrode Production plant, Bayonne, N. J.; the Republic Aviation Corp. plant in Farmingdale, N. Y.; and the Grumman Aircraft Engineering Corp., Bethpage, N. Y.

Remember! . . . APRIL is National Welded Products Month



Meetings and events at the Hotel Commodore will take place in the Grand, West and East Ballrooms located on the ballroom floor and the Windsor Suite located on the lobby floor

KEEPING YOU POSTED

By Fred L. Plummer

● April 1961 brings to AWS members and others unprecedented opportunities during the 12 days from the 10th to the 21st: unique opportunities to meet in New York and discuss welding projects with several hundred outstanding engineers, scientists, educators, fabricators, industrialists, representatives of government agencies and others coming there from the 28 member countries of the International Institute of Welding—men like President Edström of Sweden, Past-presidents Goldschmidt-Clermont of Belgium, Jaeger of the Netherlands, Biers of the USA and Guerrera of Italy, Vice-presidents Frenay of Belgium, Kihara of Japan, Plummer of USA and Vedeler of Norway, Secretaries Parsloe of United Kingdom and Leroy of France and the chairmen and vice chairmen of the fifteen IIW Technical Commissions; added opportunities to interchange information with the many hundred members of AWS who will assemble in New York during this period; to listen to some of the more than 70 technical talks (including at least fifteen to be given by representatives of foreign countries); to visit the Welding Exposition and observe and study all types of welding and allied materials, equipment and processes; to visit plants and laboratories; and to participate in social activities and other special events.

● On January 28th your Secretary met with members of the Executive Council of the International Institute of Welding in Delft, the Netherlands, to consider budget and administrative problems, to complete plans for the 1961 Annual Assembly and to review preliminary plans for the 1962 Annual Assembly which will be held in Oslo, Norway.

● President R. D. Thomas, Jr., and District Director E. E. Goehringer joined members of the Lehigh Valley Section at a dinner meeting in Allentown, Pa., on February 6th. Chairman Leon J. McGeady and Vice-chairman T. C. Fitzgibbon conducted the meeting at which President Thomas discussed AWS projects and gave a technical talk covering dramatic applications of stainless and low-alloy steels. Heavy snows prevented your Secretary from attending this meeting and greeting Past-president Harold Hill and others in attendance.

● The same snow storm caused the cancellation of plans for a meeting of the Long Island Section scheduled for February 9th.

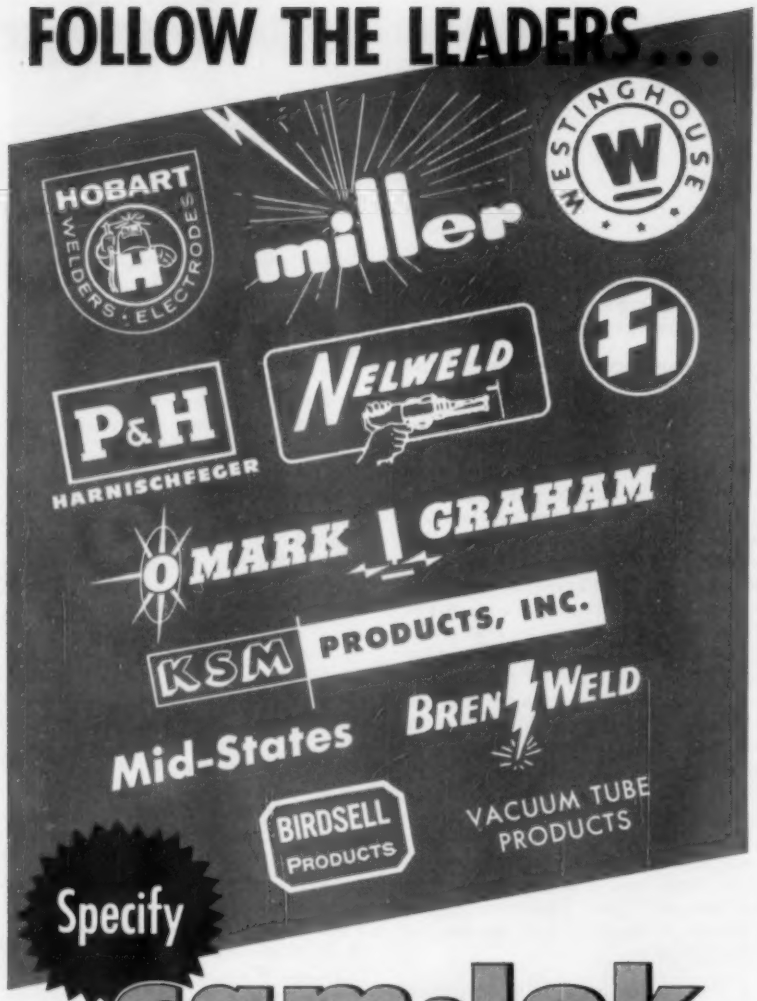
● On February 13th your Secretary traveled to Boston to join President Thomas at a meeting of this Section which was preceded by a dinner attended by an overflow crowd of enthusiastic members. Met at the airport by Vice-chairman Julius Ritter during the late afternoon, your Secretary was later greeted by officers and members of the Section including long time member Harold Card, Past-chairman Walter Ovaska, Allen Hogaboom, Allen Rosenberg, Roger Corcoran, R. J. Lawless and W. V. Smith. Chairman A. A. Barilaro and Mr. Ritter presided at the meeting as your Secretary discussed SOCIETY activities and President Thomas presented his lecture "Some Dramatic Applications of Stainless and Low-alloy Steel Welding."

● The following day President Thomas visited plants in the Boston area and then addressed a meeting of the New Hampshire Section at Manchester arranged by George L. Cutting. Your Secretary left Boston on an early flight and, after considerable delay in the air due to fog and low ceiling, landed at the airport serving Springfield and Hartford where he was met by Leon W. Jaeger, Jr., and conducted to a luncheon meeting of the Executive Committee of the Western Massachusetts Section. This was followed by a most interesting tour of the plant of The Chapman Valve Mfg. Co. as guest of Roy Trombley and Victor Bissonnette. Section Secretary Harley Goodrich then acted as guide during visits to the new buildings of Western New England College and one of the plants of The Strathmore Paper Co. At the well-attended dinner meeting of the Section at The Oaks Inn, Ivan A. MacArthur of Olin Mathieson Chemical Corp. presented an excellent discussion "Welding Aluminum—Past, Present, Future," following remarks by your Secretary concerning SOCIETY plans and activities. Chairman Trombley and Vice-chairman Jaeger introduced the speakers.

● The next morning President Thomas and your Secretary both flew to the Syracuse, N. Y., airport where they were met by H. E. Miller, Myron Schaefer, Ralph Sorton, Sam DeBoer and Harry Munson with whom they lunched after checking in at the Hotel Syracuse Country House. The afternoon was devoted to three plant visits: (1) Industrial Fabricating Co. of which Mr. Sorton is President and with Section Chairman Schaefer as guide; (2) Eagle Metalcraft with Jack Helmas (active on Section educational program) as host; and (3) the extensive facilities of Carrier Corp. Your Secretary enjoyed a comprehensive tour of these facilities as guest of National Membership Committee Chairman H. E. Miller while President Thomas conferred with other representatives of the corporation. Section officers Leon McAvoy, Dan Tyman, William Brennan and Bill Hughes assisted Chairman Schaefer in conducting the evening activities at historic LeMoyne Manor. These included a social period, an excellent dinner followed by a "coffee talk" given by your Secretary, the technical meeting at which President Thomas discussed stainless and alloy-steel welding, and a closing social period providing an opportunity for informal discussions.

● A light snow during the night was followed by good weather which improved as successive plane flights carried President Thomas and your Secretary to Detroit, Chicago and finally to Madison, Wis., where the sun was shining and there were no signs of snow. Chairman E. C. Fenska and Vice-chairman Robert Graves were waiting at the airport to provide transportation to a hotel in Madison and later to the Town and Country House in Janesville where members of the Madison-Beloit Section gathered, following an inspection tour of Fisher Body and Chevrolet plants, for a social period and dinner meeting at

FOLLOW THE LEADERS...



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which officers Fenske, Graves, K. Ellis, Fred Theiler and Garry Duchon were in charge. During the evening your Secretary was presented with a pledge card covering the full UEC quota. AWS Founder Member James W. Owen introduced President Thomas who gave the technical talk to the large audience which included students and professors from the University of Wisconsin and local vocational schools.

● An early 2-hr auto trip the next morning brought President Thomas and your Secretary to Oshkosh where President Thomas spent the day visiting several industrial plants. Fox Valley Section Vice-chairman G. H. Jacklin met your Secretary and provided transportation to Appleton in time for lunch with President N. C. Miller of Miller Electric Mfg. Co., Section Chairman John S. Teigen and others. Following a brief but delightful visit at the home of Mr. Miller with its fabulous views of the Fox River, Mr. Jacklin served as guide during a complete tour of the extensive and in many cases unique manufacturing facilities of Miller Electric Mfg. Co. Short conferences with many of the staff members were thoroughly enjoyed. Mr. Miller was host at a late afternoon cocktail party which was followed by the Section dinner at which President Thomas, Appleton Mayor Clarence Mitchell and your Secretary presented short talks. Officers Teigen and Jacklin, who presided at the technical meeting, were assisted by Stanley Manowska, Robert Hart and Thomas Krizenesky, as President Thomas and your Secretary gave their fifth presentation of their respective talks during this five-day trip.

● During the night freezing rain and fog displaced the beautiful weather and resulted in a futile trip to the airport for an early plane which circled the field for some time and then proceeded to its next scheduled stop without landing. A conveniently-timed train provided transportation to Chicago where the sun was shining and space was available on a jet plane (operating in spite of a strike of flight engineers because the one involved was based in New York and wanted to reach his home). Luck held in New York where the plane landed, after some delay, but shortly before the field was closed by fog. President Thomas had accompanied your Secretary to New York and continued to Philadelphia by train.

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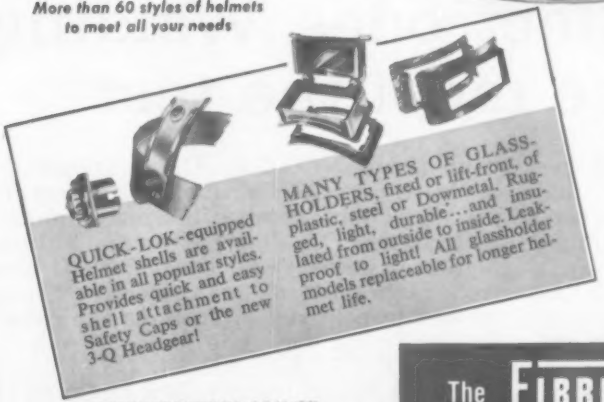

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For details, circle No. 8 on Reader Information Card

SUREWELD WELDING RODS have long been preferred by metal fabricators. A leading automobile manufacturer uses Redifluxed® No. 30, a pre-fluxed, low cost, high quality bronze rod for braze welding light gauge steel.

When welding is *Sureweld*® Electrodes, Welding Rods and Wire meet the test

The critical jobs . . . those that demand unusually high performance under exacting conditions, that require *extra* ability-to-perform . . . put fabricating methods, equipment and materials to the real test.

It's on jobs like these that SUREWELD electrodes, welding rods and wire prove they are *built-better* to do *better-work*. Each are manufactured under a program of exacting quality control, beginning with testing of raw materials and continuing through every step in production to final testing of the finished product.

Find out what SUREWELD electrodes, welding rods and wire can do for you. Ask your nearby NCG Sales Office, Distributor or Dealer for SUREWELD Data Sheets giving complete and detailed information on each SUREWELD product and its applications.

Also, write today for the new NCG Electrode Data Book . . . an informative 20 page catalog to help you in choosing the correct electrode for any application. Ask for NH-644-E-1D. NATIONAL CYLINDER GAS DIVISION OF CHEMETRON CORPORATION, 840 N. Michigan Avenue, Chicago 11, Illinois.

NCG sales offices, distributors, and dealers in all principal cities. Consult the "Yellow" pages for the one nearest you.

NCG, SUREWELD, DUAL SHIELD, REDIFLUXED are Trademarks
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SUREWELD WELDING WIRE is rapidly growing in use. A heavy equipment manufacturer has cut production costs with the Dual Shield, CO_2 automatic and semi-automatic, welding process, and No. 111A multiple-pass wire for welding mild steel.

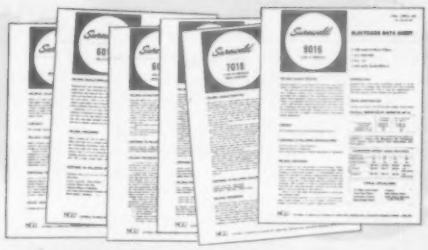
SUREWELD ELECTRODES are used for all kinds of jobs. No. 6013, developed for welding light and heavy gauge steel, provides equally good results when welding vertically down, overhead, horizontal or flat fillet welds.

critical

NCG®

NATIONAL CYLINDER GAS

Division of CHEMETRON *Corporation*



SUREWELD DATA SHEETS . . . Complete, detailed information; welding characteristics, welding procedures, color identifications, physical properties of deposit metal, etc.

NEW ELECTRODE CARTON . . . Strong, moisture-resistant carton for maximum protection. Also, a new zipper opens carton easily, about one-third comes away and the remainder provides excellent temporary storage.

NEW ELECTRODE SOUND, COLOR STRIP FILM —"How to Select an electrode" is available from your nearby NCG sales office. See it soon.

For details, circle No. 9 on Reader Information Card

EDUCATIONAL ACTIVITIES

42nd Annual Meeting and Welding Show

The month of April is National Welded Products Month—it is also the month in which the International Institute of Welding will be held for the first time on American soil. It is also the month that our 42nd Annual Meeting will be held. It is also the month of the Welding Show.

All of these activities have to be publicized and the Publicity Committee, under the capable chairmanship of Ron Lawson, has held several meetings to determine how to handle each activity. Publicity chairmen throughout the country publicized National Welded Products Month in local areas and material had to be prepared to help them with this promotion.

The Planning Manual was the result and it has met with a great reception. Publicity chairmen all over the country are following many of its recommendations and the resulting publicity is expected to be greater this year than ever before. Many publicity chairmen have told us they have already contacted mayors and governors with very hopeful results. We should receive more proclamations than ever this year and greater recognition by merchants, city officials and companies. If we can receive the proclamations in time we will have them reproduced and on display in New York. It is hoped, therefore, that publicity chairmen will make every effort to get the proclamations to the Secretary at the earliest possible moment.

International Institute of Welding

This event in itself has great publicity value. The number of registrations received from abroad indicates that a record number of persons are going to visit New York for the IIW Assembly and the AWS Meeting and Show.

Many are signing up for the various tours and other side activities. This means that from April 10th through April 21st meetings will be held, papers given, products exhibited—all on the subject of welding.

A press room will be maintained in the Sheraton-Atlantic Hotel and we are hoping to place many stories concerning the visiting dignitaries from abroad.

We have contacted the United Nations and we are very hopeful that an official welcome will be given to these delegations and an invitation to visit the U. N. by the Secretariat.

We are contacting the various embassies involved and we are hoping that each will give recognition to its own nationals.

Annual Meeting

The annual Meeting will, of course, be held at the Commodore Hotel in New York. As usual we will maintain a press room at the Commodore in order to get news and information to the press as rapidly as possible.

All members of the AWS attending the meeting can be of tremendous assistance if they will keep in touch with the press room and give any newsworthy information they have. Reporters and editors are constantly asking us "What's new?" They want to know the trends in welding, equipment and what the future holds for welding.

The people who can give authoritative information of this kind are attending the meeting and can be of invaluable assistance in obtaining wide-spread coverage in newspapers and magazines. Editors are most anxious to print such information but they find it extremely difficult to obtain. Here is our opportunity to give them just what they want.

Welding Show

This year the AWS will maintain its own booth at the show. This booth will be manned with personnel able to give all information upon SOCIETY activities. Enrollment forms will be available and many new members should be signed up during the show. The WELDING JOURNAL will be represented and the Treasurama, sponsored by the Publicity Committee, will be directed from the booth.

This year the Publicity Committee discussed the problem of how to obtain an unbiased opinion from those attending the Welding Show, and how to get answers to certain questions all exhibitors would like answered, but have no opportunity of asking. They came up with the idea of a contest similar to the Treasurama held by the WELDING JOURNAL last year. It was felt that if a contest be held and worthwhile prizes given, these questions could be the motivating factor in the contest and the answers received would give exhibitors much valuable information. The prizes this year will be: 1 portable TV set, 1st prize; 1 transistor radio, 2nd prize; 1 electric razor, 3rd prize.

AWS School of Welding Technology

Five-day Course on Pipe Welding

Location: New York City.
Date: May 15–19, 1961.
Fee: $75.
Who: The course is designed to assist the needs of the engineer whose company wishes to make use of the latest developments in pipe welding.
Why: To give him a grasp of the metallurgical considerations involved in the welding of ferrous and nonferrous piping and to introduce him to applications and design considerations.

Enrollments are limited to fifty and lists will be closed immediately after fifty applications have been accepted. Plan to attend this course and take advantage of the latest and most authoritative information on pipe welding techniques. Send for prospectus and application form, by addressing Arthur L. Phillips, Secretary, Information & Education, 33 W. 39th St., New York 18, N. Y.

YOU HAVE TO WEAR MANY HATS

You can't get "complete" welding information from an equipment salesman who's restricted to two or three processes. Metalworking technology is continuously being advanced— first came Submerged Arc welding, then Tig and Mig fusion, Tig and Mig spot, CO_2-flux, CO_2-Mig, Short Arc, Plasma Arc cutting, surfacing and welding. Because LINDE developed *all* these processes, your LINDE field representative supplies the know-how and equipment for a *complete* line of inert-gas and continuously-fed electrode welding and cutting processes. He's one of our 200-plus field specialists with year-after-year experience in the *use* of these processes. And he's backed by over 100 laboratory engineers who *developed* the processes. His recommendations are based on your needs, not his.

LINDE COMPANY
Division of Union Carbide Corporation
270 Park Avenue, New York 17, N.Y.

UNION CARBIDE

For details, circle No. 10 on Reader Information Card

The contest is open to all attending the Welding Show, excluding AWS staff members and the Publicity Committee members. Each contestant will have to tour the exhibit area and visit each booth before he can complete the form and this will benefit both the exhibitor and attendee. The names will probably be drawn on the Thurday afternoon and contestants need not attend the drawing to be eligible for the prizes.

As soon as it is practicable after the show is over, all entries will be tabulated and the information prepared for distribution to those interested. It is felt that this will be a valuable contribution to exhibitors and may be a guide for future displays. It is always easier to obtain attendance if an exhibitor is showing what his public wants to see.

In New York City preparations are under way to celebrate National Welded Products Month. The New York Section is very active and is trying to interest the various stores to hold displays and to give recognition to welding.

Civic authorities are cooperating and on Monday, April 17th, the historic Times Square in the heart of New York will have its name changed to Welding Square. This will be quite a ceremony and details will be available later.

Again this year we will get out a daily news sheet giving highlights of the meetings and Welding Show, and giving up-to-the-minute details of what is happening, and what will happen the following day. Members visiting New York should obtain their daily copy of the news sheet since this is the only way they can learn of any changes in the program or what is happening from hour to hour. Details such as the changing of Times Square to Welding Square cannot always be publicized much in advance and it is only through the medium of a daily news sheet that such information can be given in time for it to be of use to members.

The Convention and Visitors' Bureau of New York is cooperating and has agreed to give the SOCIETY the use of its window for the period April 10–25. A window display is being arranged which will highlight the various places of interest and show how welding is influencing fabrication and construction in the city. This window is situated on 42nd street midway between the Commodore Hotel and Grand Central Station. Literally millions of people pass the window in the course of a week and its publicity value will be difficult to estimate.

This is expected to be our biggest show, and one of the most important meetings we have ever held. Plan to attend the meeting and show this year; you will learn much—and enjoy more.

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APRIL is NATIONAL WELDED PRODUCTS MONTH

MEET THE MILLER A-C "S" SERIES

A BEST BUY by ANY TEST

Compare! Comparison proves that amp for amp and dollar for dollar this is your best deal in a heavy duty a-c welder.

Low first cost teams up with maintenance-free reliability to make the "S" very big on value.

Yet everything needed for top performance is here, including movable coil design, silicon steel cores, class B insulated copper coils, superior cooling, and 80 volts open circuit for instantaneous arc starting. Case is heavy gauge steel under baked enamel lifetime finish with dead front construction.

Complete information on the 300 or 500 ampere Miller "S" a-c welders will be forwarded promptly upon request.

miller ELECTRIC MANUFACTURING COMPANY • APPLETON, WISCONSIN

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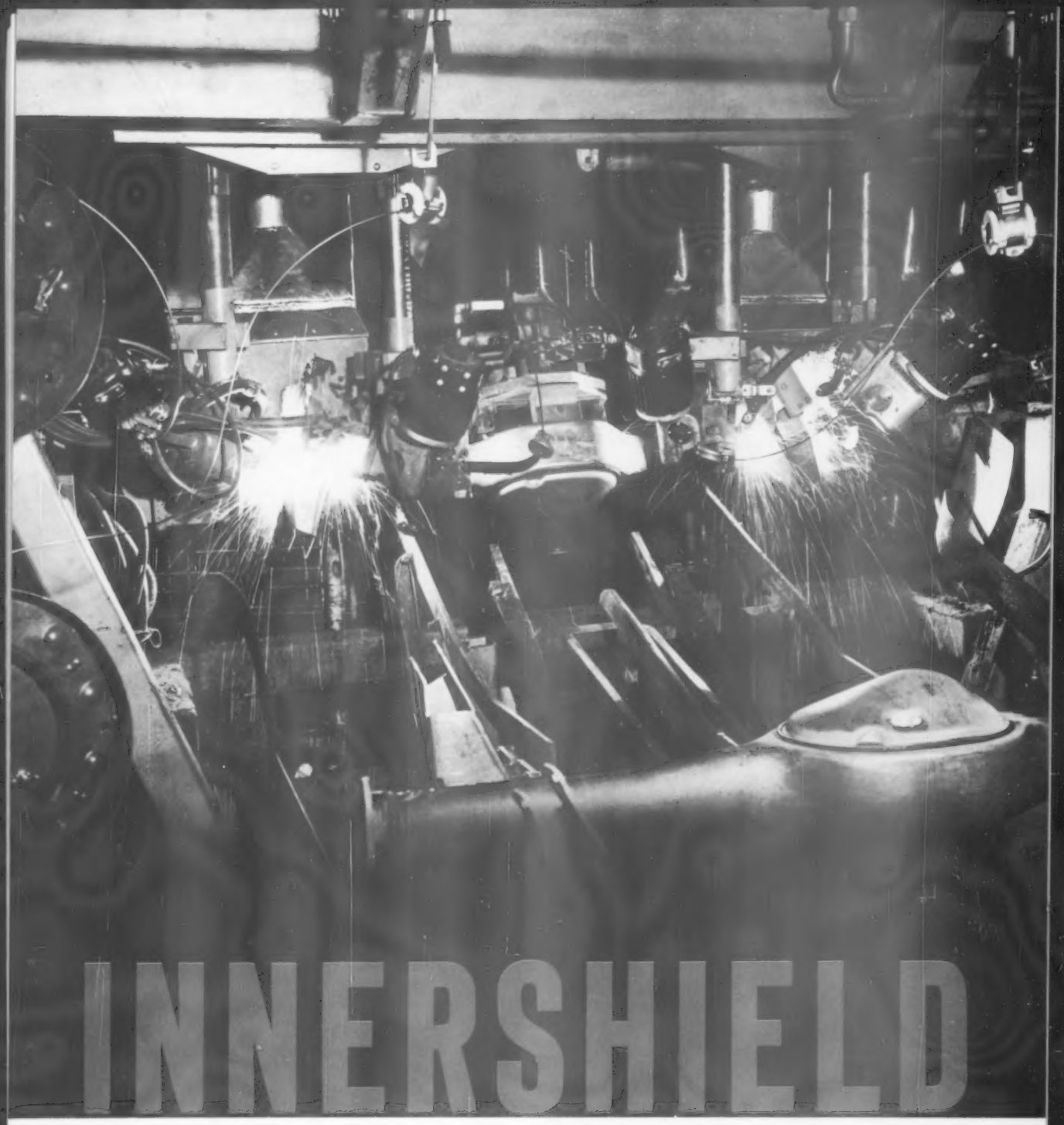
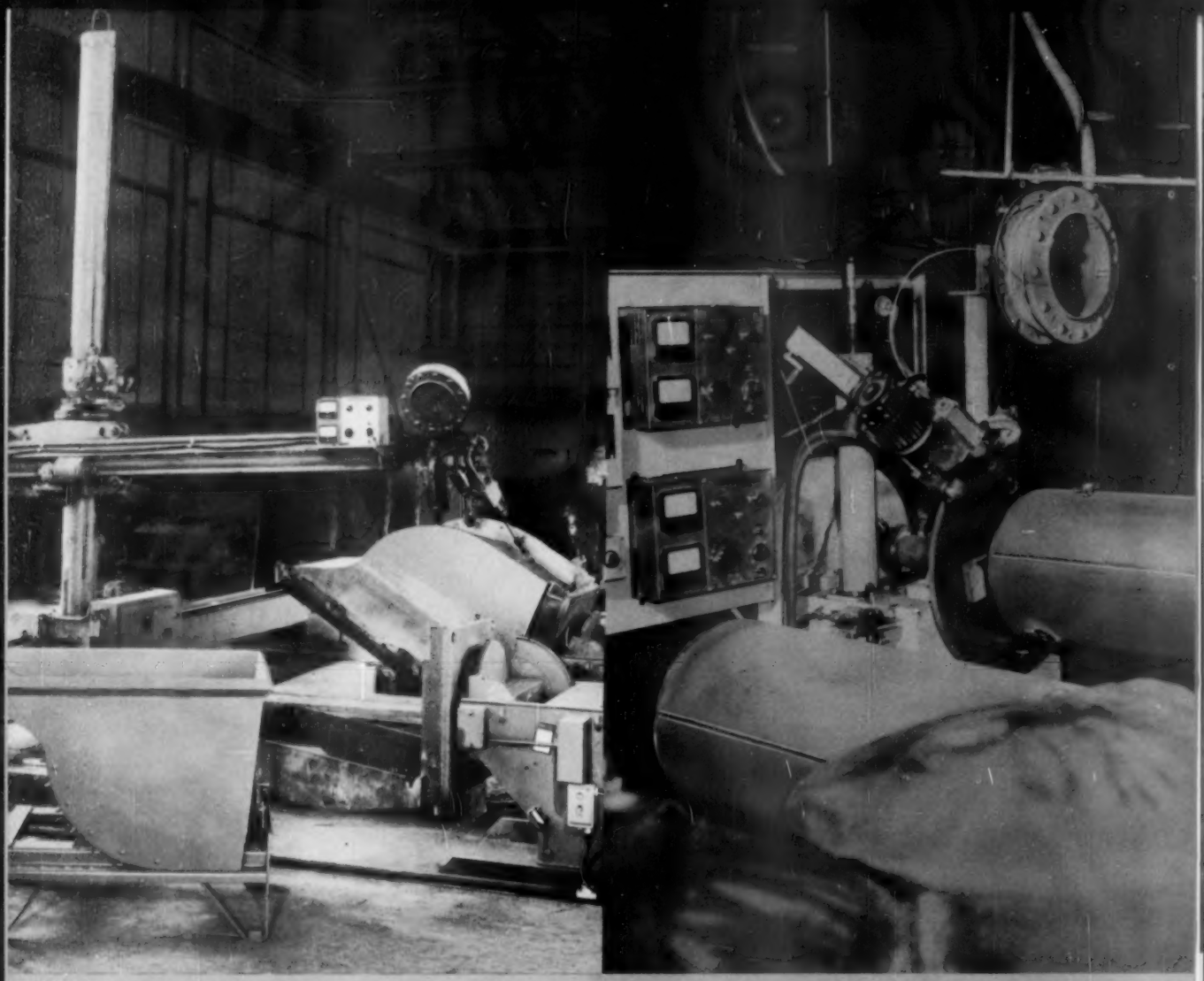


Speed. Simplicity. Low cost. These you get with Lincoln full-automatic Innershield... a new process that welds up to 300 ipm. Tubular electrode contains all ingredients for welding. Needs no CO_2, Argon or granular flux. Unbelievable? Read all the facts about this amazing process.



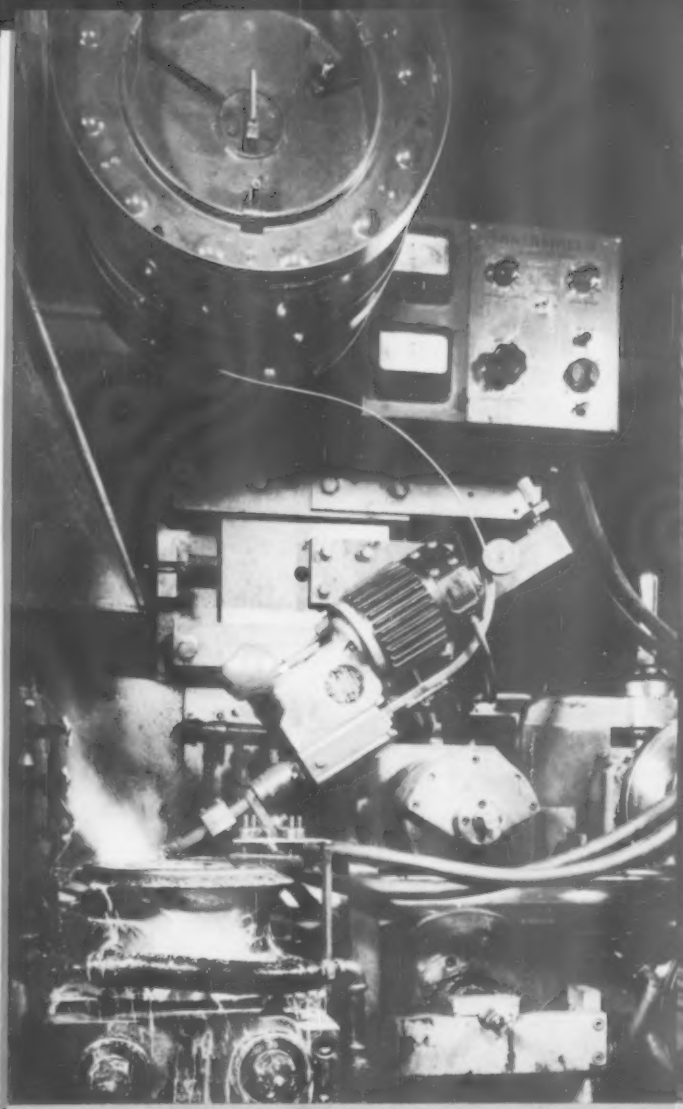
Innershield makes automatic welding of difficult corner welds easy. Poor fit-up conditions are handled at an average speed of 90 ipm, five times faster than previous hand welding techniques. And the operating factor is vastly improved, too.

Dual-head setup welds water tank end shells complete in 12 seconds! No costly slag removal problem. No need for expensive piping and manifolding as with gas-shielded processes. Inventories and storage space reduced, purchasing simplified.

THIS IS FULL-AUTOMATIC

INNERSHIELD

ON THE JOB



Innershield makes continuous butt weld at 120 ipm. Special tubular electrode eliminates flux used in submerged arc process and intricate manifold system of inert gas process. Reduces inventories, simplifies purchasing, cuts storage space.

Semi-automatic Innershield Squirt is ideal for short, intermittent, single-pass welding on parts such as these building trusses. Weld quality improved. Continuous 50-pound coil electrode eliminates time-consuming electrode changing.

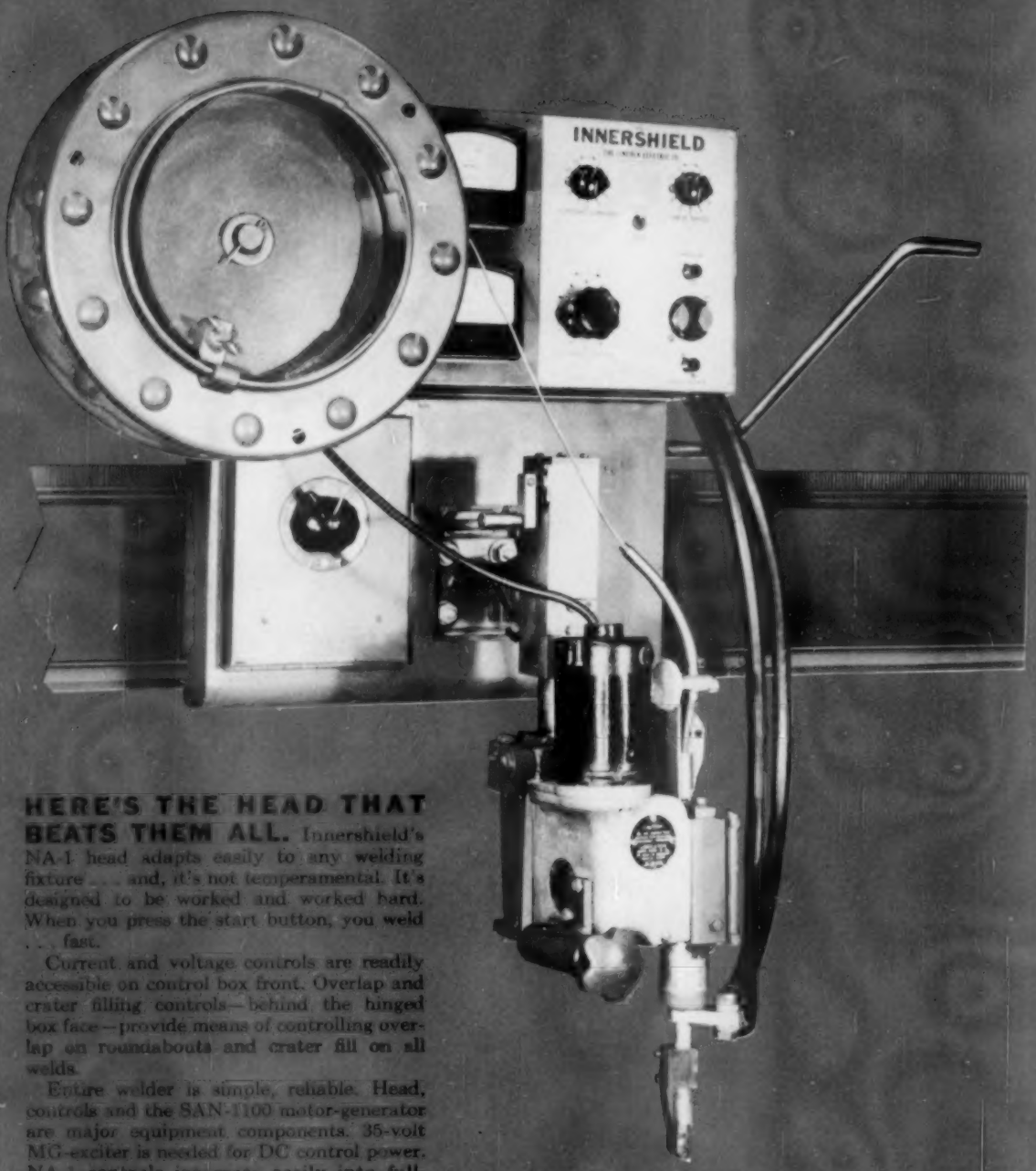
Imagine a welding process so fast it outruns all existing fixtures . . . that exceeds all other automatic processes in fast follow ability . . . that is so practical that it has even replaced manual welding . . . that is lower in installation and operating cost than any other full-automatic process (particularly gas). Such a process exists. It's called Innershield.

Full-automatic Innershield was developed primarily for welding thin materials (down to 16-gage), but it has proved itself equally as capable of making small, high-speed welds on heavier plate.

Obviously, full-automatic Innershield is a natural for knocking out a lot of work—fast. Why not find out more about this hot, new welding process now? See your Lincoln field sales engineer . . . a welding specialist. And ask him for Bulletin No. 5300.1 which describes the Innershield process and its application in both full and semi-automatic equipment. Or write, The Lincoln Electric Company, Cleveland 17, Ohio.

LINCOLN WELDERS

See Innershield demonstrated at our Welding Show Booth



HERE'S THE HEAD THAT BEATS THEM ALL. Innershield's NA-1 head adapts easily to any welding fixture . . . and, it's not temperamental. It's designed to be worked and worked hard. When you press the start button, you weld . . . fast.

Current and voltage controls are readily accessible on control box front. Overlap and crater filling controls—behind the hinged box face—provide means of controlling overlap on roundabouts and crater fill on all welds.

Entire welder is simple, reliable. Head, controls and the SAN-1100 motor-generator are major equipment components. 35-volt MG-exciter is needed for DC control power. NA-1 controls integrate easily into full-automatic fixture controls.

LINCOLN WELDERS

THE LINCOLN ELECTRIC COMPANY

Dept. WW-8 • Cleveland 17, Ohio

THE WORLD'S LARGEST MANUFACTURER OF ARC WELDING EQUIPMENT AND ELECTRODES

TECHNICAL PAPERS SESSIONS

1961

AWS 42ND ANNUAL MEETING and AIEE ELECTRIC WELDING CONFERENCE

APRIL 17–21 • HOTEL COMMODORE, NEW YORK CITY

REGISTRATION

MEZZANINE FLOOR
HOTEL COMMODORE

Sunday, April 16 • 3:00 P.M. to 6:00 P.M.
Monday, April 17 • 8:00 A.M. to 4:00 P.M.
Tuesday, April 18 • 8:00 A.M. to 4:00 P.M.
Wednesday, April 19 • 8:30 A.M. to 4:00 P.M.
Thursday, April 20 • 8:30 A.M. to 3:00 P.M.
Friday, April 21 • 8:30 A.M. to 11:00 A.M.

Registration Fee:
AWS and AIEE Members $5
Nonmembers $10

APRIL 17, MONDAY MORNING

GRAND BALLROOM (Ballroom Floor)

10:00 A.M.—Official Opening and Business Session

CHAIRMAN—J. E. Dato, Linde Company

ADDRESS—R. D. Thomas, Jr., President, AWS

NATIONAL AWARDS

ADAMS LECTURE—Studies on Cracking of and Transformation in Steels During Welding, by H. Granjon, Institut de Soudure, France

APRIL 17, MONDAY AFTERNOON THREE SIMULTANEOUS SESSIONS, 2:00 P.M.

Papers "A" Start at 2:00 P.M.
Papers "B" Start at 2:50 P.M.
Papers "C" Start at 3:40 P.M.

1. Processes

(SPONSORED BY INTERNATIONAL INSTITUTE OF WELDING)

WINDSOR BALLROOM (Lobby Floor)

Chairman

A. N. Kugler, Air Reduction Sales Co.

Co-Chairman

H. G. Taylor, British Delegation, IIW

A. Notes on the Appreciation of Brazing Filler Metals and Fluxes
by C. G. Keel, Switzerland, G. M. A. Blanc, Switzerland, and J. Colbus, West Germany

B. Gas Mixtures in Shielded-arc Welding with Consumable Electrode
by M. M. Komers, West Germany, and L. Wolff, West Germany

C. The Solutions Adopted in Some Difficult Applications of Flash Welding
by M. E. Bylin, Sweden

2. Welded Structures

EAST BALLROOM (Ballroom Floor)

Chairman

C. L. Kreidler, Lehigh Structural Steel Co.

Co-Chairman

LaMotte Grover, Air Reduction Sales Co.

A. Modern Welded Design of Multistory Structures
by Omer W. Blodgett, The Lincoln Electric Co.

B. Fatigue Behavior of Welded Joints in Reinforcing Bars for Concrete
by W. W. Sanders, Jr., P. G. Hoadley and W. H. Munse, University of Illinois

C. Residual Stresses in Welded Plates
by N. R. Nagaraja Rao and Lambert Tall, Lehigh University

3. Alloy Fabrication

WEST BALLROOM (Ballroom Floor)

Chairman

C. E. Hartbower, Manufacturing Laboratories, Inc.

Co-Chairman

R. L. Hackman, Linde Co.

A. Fusion and Resistance Welding of Columbium Alloys
by W. R. Young, General Electric Co.

B. Heat Treatment and Welding Characteristics of B120VCA Titanium-alloy Sheet
by John F. Rudy, Frank A. Crossley and Harry Schwartzbart, Armour Research Foundation

C. Welded Rocket Cases are Reliable at 200,000 Psi Yield Strength
by E. J. Wilson, Jr., Redstone Arsenal

APRIL 17, MONDAY AFTERNOON

4:30 to 6:00 P.M.—GRAND BALLROOM (Ballroom Floor)

Educational Lecture Series (Part I)

Heat Sources, Heat Flow and Heat Effects in Welding
by N. N. Rykalin, USSR

CHAIRMAN
E. C. Miller, Union Carbide Nuclear Co.
CO-CHAIRMAN
E. E. Goehringer,
The Lincoln Electric Co.

APRIL 18, TUESDAY MORNING THREE SIMULTANEOUS SESSIONS, 9:30 A.M.

Papers "A" Start at 9:30 A.M.
Papers "B" Start at 10:20 A.M.
Papers "C" Start at 11:10 A.M.

4. Resistance Welding

(SPONSORED BY A.I.E.E. ELECTRIC WELDING COMMITTEE)

WINDSOR BALLROOM (Lobby Floor)

Chairman
C. R. Dixon, Reynolds Metals Co.

Co-Chairman
Morris Thomas, General Motors Institute

A. Standards for Resistance Welding Control
by R. C. Mierendorf, The Square D Co.
B. Applying Static Control to Resistance Welding
by C. F. Meyer and W. J. Brown, Square D Co.
C. Instrumentation in Automotive Resistance Welding
by Edward J. Zulinski, The Ford Motor Co.
D. Load Control for Resistance Welding
by R. E. Rogers, Instrument Control Co.

5. Brazing

EAST BALLROOM (Ballroom Floor)

Chairman
F. W. Hussey, Frankford Arsenal

Co-Chairman
R. L. Peaslee, Wall Colmonoy Corp.

A. Grain-boundary Penetration and Base Metal Erosion in High-temperature Brazing
by Nikolajs Bredzs and Harry Schwartzbart, Armour Research Foundation
B. Brazing Ultra-high Strength Steel
by Melvin J. Albom and R. E. Anderson, Aerojet General Corp.
C. Brazing of Sandwich Structures of Columbium Alloys
by Mel M. Schwartz, Martin Co.

6. Arc Welding

WEST BALLROOM (Ballroom Floor)

Chairman
H. A. Sosnin, Pipe Engineering and Design

Co-Chairman
R. T. Telford, Linde Co.

A. Dip-transfer Welding of High-pressure Pipe
by W. W. Walker, Air Reduction Sales Co.
B. An Automatic Process for Welding Girth Joints in Steel Pipelines
by J. W. Nelson, G. E. Faulkner and P. J. Rieppel, Battelle Memorial Institute, and H. C. Cook, Esso Research and Engineering Co.
C. Semiautomatic Vapor-shielded Welding: A New Process
by R. A. Wilson, The Lincoln Electric Co.

WELDING SHOW EXHIBITS AND DEMONSTRATIONS
NEW YORK COLISEUM

Hours of the Exposition
Tuesday, April 18 • 10:00 A.M. to 10:00 P.M.
Wednesday, April 19 • 10:00 A.M. to 10:00 P.M.
Thursday, April 20 • 10:00 A.M. to 6:00 P.M.

Admission by Registration

APRIL 18, TUESDAY AFTERNOON

4:30 to 6:00 P.M.—GRAND BALL ROOM (Ballroom Floor)

Educational Lecture Series (Part II)

Heat Sources, Heat Flow and Heat Effects in Welding
by N. N. Rykalin, USSR

CHAIRMAN
E. C. Miller, Union Carbide Nuclear Co.
CO-CHAIRMAN
E. E. Goehringer,
The Lincoln Electric Co.

APRIL 18, TUESDAY AFTERNOON THREE SIMULTANEOUS SESSIONS, 2:00 P.M.

Papers "A" Start at 2:00 P.M.
Papers "B" Start at 2:50 P.M.
Papers "C" Start at 3:40 P.M.

7. Arc Welding

(SPONSORED BY A.I.E.E. ELECTRIC WELDING COMMITTEE)

WINDSOR BALLROOM (Lobby Floor)

Chairman

L. P. Winsor, Rensselaer Polytechnic Institute

Co-Chairman

G. W. Garman, General Electric Co.

A. Electrical and Metallurgical Factors Influencing Welding-arc Stability
by Jerry E. Ginn, Boeing Airplane Co.

B. Wave Shape Effect on Alloying and Arc Stability of Alternating Current Tungsten Inert-arc Welding
by Thomas B. Correy, General Electric Co.

C. Some New Concepts in Power Supplies and Arc Initiation Applied to Gas Tungsten-arc Spot Welding
by Marcel Sommeria, Sciaky Bros. Inc.

8. Brazing

EAST BALLROOM (Ballroom Floor)

Chairman

H. Schwartzbart, Armour Research Foundation

Co-Chairman

A. J. Cross, Englehard Industries

A. Exothermic Brazing
by Roger A. Long, Narmco Industries, Inc.

B. Argon Brazing of Difficult-to-braze Metals
by J. W. Hill, Linde Company

C. Eutectic Brazing of Zircaloy-2 to Type 304 Stainless Steel
by W. A. Owczarski, General Electric Co.

9. Applications

WEST BALLROOM (Ballroom Floor)

Chairman

J. J. MacKinney, Budd Co.

Co-Chairman

L. E. Powers, Linde Co.

A. A Welded, Tubular-bucketed Turbine Wheel
by E. J. Clark, General Electric Co.

B. New Method of Backing Double-V Weld Joints in Steel Plate
by J. N. Cordea, R. M. Evans and P. J. Rieppel, Battelle Memorial Institute

C. Creative Architectural Design with Welded Space Structures
by M. P. Korn, Consulting Engineer

APRIL 19, WEDNESDAY MORNING TWO SIMULTANEOUS SESSIONS, 9:30 A.M.

Papers "A" Start at 9:30 A.M.
Papers "B" Start at 10:20 A.M.
Papers "C" Start at 11:10 A.M.

10. Welded Structures

(SPONSORED BY INTERNATIONAL INSTITUTE OF WELDING)

EAST BALLROOM (Ballroom Floor)

Chairman

A. Gatewood, American Bureau of Shipping

Co-Chairman

V. Guerrera, Italian Delegation, IIW

A. Evaluation of the Fatigue Limit of Welded Steel Assemblies Using a Single Welded Specimen or Test Element
by R. Cazaud and H. deLeiris, France

B. The Calculation of Welded Connections
by A. Van Douwen, The Netherlands

C. Pressure Vessel Design Requirements in the Future
by W. B. Carlson, United Kingdom

11. Arc Welding

(SPONSORED BY A.I.E.E. ELECTRIC WELDING COMMITTEE)

WEST BALLROOM (Ballroom Floor)

Chairman

E. J. Limpel, A. O. Smith Corp.

Co-Chairman

C. E. Pflug, American Motors Corp.

A. A Double-taper Tungsten-arc Welding Control
by Austin Dixon, Westinghouse Electric Corp.

B. New Developments in Electron Beam Welding Machines
by J. L. Solomon, Sciaky Bros., Inc.

C. Development of a Power Supply for Stored-energy Arc Welding
by Cecil C. Stone and Robert A. Noland, Argonne National Laboratory

APRIL 19, WEDNESDAY AFTERNOON TWO SIMULTANEOUS SESSIONS, 2:00 P.M.

Papers "A" Start at 2:00 P.M.
Papers "B" Start at 2:50 P.M.
Papers "C" Start at 3:40 P.M.

12. Weldability

(SPONSORED BY INTERNATIONAL INSTITUTE OF WELDING)

EAST BALLROOM (Ballroom Floor)

Chairman

R. D. Stout, Lehigh University

Co-Chairman

H. E. Jaeger, Netherlands Delegation, IIW

A. The Role of Hydrogen in Arc Welding with Covered Electrodes
by N. Christensen, Norway

B. Influence of Residual Stresses and Metallurgical Changes on Low-stress Brittle Fractures in Welded Steel Plates
by A. A. Wells, United Kingdom

C. Inspection and Measurements of Properties of Welds on Plastics
by G. A. Homes, Belgium

13. Resistance Welding

WEST BALLROOM (Ballroom Floor)

Chairman

T. E. Jones, Precision Welder & Flexopress Corp.

Co-Chairman

F. Wallace, Pratt & Whitney

A. Fatigue Testing Resistance-spot Welds in Shear
by E. E. Weismantel, Beryllium Corp., and D. S. Kalbfleisch, The Budd Co.

B. Properties of Flash-welded Molybdenum
by E. G. Thompson and H. Binder, The Marquardt Corp., and H. Collins, Dresser Manufacturing Div.

C. Inserted-shim Projection Welding of a Continuous Rod Mat
by Keh-Chang Wu and R. E. Lewis, Watervliet Arsenal

APRIL 19, WEDNESDAY AFTERNOON

2:00 to 4:00 P.M.—WINDSOR BALLROOM (Lobby Floor)

Missiles and Rockets Welded Fabrication

MODERATOR

D. B. Howard, ACF Industries, Inc.

PANELISTS

D. W. Kinsey, U. S. Steel Corp.
R. D. Libert, A. O. Smith Corp.
J. W. Jakubowski, General Electric Co.
J. F. Rudy, Armour Research Foundation

APRIL 20, THURSDAY MORNING THREE SIMULTANEOUS SESSIONS, 9:30 A.M.

Papers "A" Start at 9:30 A.M.
Papers "B" Start at 10:20 A.M.
Papers "C" Start at 11:10 A.M.

14. Electroslag Welding

WINDSOR BALLROOM (Lobby Floor)

Chairman

N. G. Schreiner, Linde Co.

Co-Chairman

W. H. Wooding, Arcos Corp.

A. Electroslag Welding in West European Countries—Improvement and Applications
by F. G. Danhier, Belgium

B. and C. Electroslag Welding of Very Thick Materials
by B. E. Paton, USSR

15. Research and Weldability

EAST BALLROOM (Ballroom Floor)

Chairman

A. Clemens, Westinghouse Electric Corp.

Co-Chairman

C. M. Adams, Jr., Mass. Institute of Technology

A. A New Technique for Studying Residual Stresses
by D. C. Martin and Koichi Masubuchi, Battelle Memorial Institute

B. The Cruciform Test for Plate-cracking Susceptibility, II
by W. P. Hatch, Jr., Watertown Arsenal Laboratories, and L. E. Poteat, North Carolina State College

C. Hydrogen and Delayed Cracking in Steel Weldments
by E. P. Beachum, Bethlehem Steel Co., H. H. Johnson, Cornell University, and R. D. Stout, Lehigh University

16. Arc-spot Welding

WEST BALLROOM (Ballroom Floor)

Chairman

T. W. Shearer, General Motors Corp.

Co-Chairman

J. H. Headapohl, Hobart Bros.

A. Consumable-electrode Spot Welding
by J. A. Howery and G. F. Mack, National Cylinder Gas Co.

B. Gas-shielded-arc Consumable-electrode Spot Welding in Industry
by R. P. Sullivan, Linde Company

C. Semiautomatic Tungsten-arc Spot Welding of Stainless Steels and High-temperature Alloys
by R. J. Campbell and D. R. Miller, General Electric Co.

APRIL 20, THURSDAY AFTERNOON TWO SIMULTANEOUS SESSIONS, 2:00 P.M.

Papers "A" Start at 2:00 P.M.
Papers "B" Start at 2:50 P.M.
Papers "C" Start at 3:40 P.M.

17. Processes

WINDSOR BALLROOM (Lobby Floor)

Chairman

P. J. Rieppel, Battelle Memorial Institute

Co-Chairman

J. A. Howery, National Cylinder Gas

A. New Concepts for Oxygen Cutting
by C. C. Anthes, Linde Company

B. Advances in Electron-beam Welding Techniques
by R. D. Mann, Air Reduction Sales Co.

C. Ultrasonic Welding, Engineering, Manufacturing and Quality Control Problems
by J. Koziarski, The Martin Co.

18. Nuclear Components

EAST BALLROOM (Ballroom Floor)

Chairman

G. W. Oyler, Texas Instruments Inc.

Co-Chairman

R. Sutton, International Nickel Co.

A. Inconel Deposited Weld Metal for Nuclear-component Parts
by R. W. Minga and W. H. Richardson, Combustion Engineering, Inc.

B. Insulation Attachment by Welding for an Aircraft Nuclear Propulsion Powerplant
by R. J. Campbell and T. D. McLay, General Electric Co.

C. The Brazing of Graphite
by R. G. Donnelly and G. M. Slaughter, Oak Ridge National Laboratory

19. Research and Weldability

WEST BALLROOM (Ballroom Floor)

Chairman

G. E. Claussen, Arcrods Corp.

Co-Chairman

W. D. Doty, U. S. Steel Corp.

A. Transition-temperature Correlations in Constructional Alloy Steels
by G. M. Orner and C. E. Hartbower, Manufacturing Laboratories, Inc.

B. The Yield Strength of E9018 Weld Metal
by W. L. Wilcox and H. C. Campbell, Arcos Corp.

C. Ferritic Welding of Steel Armor
by Z. J. Fabrykowski, U. S. Army Ordnance Tank-Automotive Command

APRIL 21, FRIDAY MORNING THREE SIMULTANEOUS SESSIONS, 9:30 A.M.

Papers "A" Start at 9:30 A.M.
Papers "B" Start at 10:20 A.M.
Papers "C" Start at 11:10 A.M.

20. Submerged-arc Welding

WINDSOR BALLROOM (Lobby Floor)

Chairman

A. G. Hogaboom, Bethlehem Steel Co.

Co-Chairman

R. S. Hale, The Lincoln Electric Co.

A. Observations on Electrode-melting Rates during Submerged-arc Welding
by Michael H. Robinson, ACF Industries, Inc.

B. Advancements in Submerged-arc Welding of High-impact Steels
by R. A. Kubli and W. B. Sharav, Linde Company

C. Flux and Filler-wire Developments for Submerged-arc Welding HY-80 Steel
by Wallace J. Lewis, G. E. Faulkner and P. J. Rieppel, Battelle Memorial Institute

21. Gas-shielded Welding

EAST BALLROOM (Ballroom Floor)

Chairman

J. J. Chyle, A. O. Smith Corp.

Co-Chairman

B. Gates, Budd Co.

A. Some Metallurgical Aspects of CO_2-shielded Arc Welding
by M. D. Randall and P. J. Rieppel, Battelle Memorial Institute

B. Argon-shielded Alternating-current Metal-arc Welding
by C. R. Sibley, Air Reduction Sales Co.

C. CO_2-shielded Welding Horizontal Joints of Oil Storage Tanks
by Paul W. Turner, Union Carbide Nuclear Co.

22. Research and Weldability

WEST BALLROOM (Ballroom Floor)

Chairman

Helmut Thielsch, Grinnell Co.

Co-Chairman

R. W. Tuthill, Air Reduction Sales Co.

A. Welding of 12% Chromium Martensitic Stainless Steels
by C. H. Kreischer, A. E. Near and J. Cothren, General Electric Co.

B. Lime-coated Versus Titania-coated Stainless Steel Electrodes
by B. S. Payne, Jr., G. J. Dormer and L. R. Haslip, Pfaudler-Permutit, Inc.

C. Effects of Repeated Repair Welding of Two Aluminum Alloys
by F. G. Nelson, Aluminum Co. of America

Other Activities at Hotel Commodore

April 17th, Monday

8:00 A.M.—Authors' Breakfast, Parlor "C"
2:00 P.M.—Exposition Committee Meeting, Parlor "D"
2:00 P.M.—Open Meeting—National Nominating Committee Policy, Parlor "C"
3:00 P.M.—Closed Meeting—National Nominating Committee Policy, Parlor "C"
4:30 P.M.—Educational Lecture Series, Grand Ballroom
6:00 P.M.—President's Reception, Windsor Ballroom
8:00 P.M.—Annual Banquet, Grand Ballroom

April 18th, Tuesday

8:00 A.M.—Authors' Breakfast, Parlor "C"
8:00 A.M.—District No. 4 Breakfast Meeting, Parlor "D"
10:00 A.M.—Member Classes Committee Meeting, Parlor "F"
12:00 Noon—District No. 9, Luncheon Meeting, Coliseum
2:00 P.M.—Membership Activities Committee Meeting, Parlor "F"
4:00 P.M.—Subcommittee 1—Resistance Welding Committee Meeting, Parlor "G"
4:30 P.M.—Educational Lecture Series, Grand Ballroom
7:00 P.M.—Ohio State University Student Alumni Dinner, Parlors "B" and "C"

April 19th, Wednesday

8:00 A.M.—Authors' Breakfast, Parlor "C"
8:00 A.M.—District No. 1, Breakfast Meeting, Parlor "B"
9:00 A.M.—Missiles and Rockets Welded Fabrication Committee Meeting, Windsor Court
9:30 A.M.—WRC Aerospace Advisory Committee Meeting, Parlor "G"
9:30 A.M.—Resistance Welder Manufacturers Association Meeting, Room No. 102
10:00 A.M.—Districts Council Meeting, Parlor "D"
12:00 Noon—Resistance Welder Manufacturers Association Luncheon, Room No. 103
2:00 P.M.—District No. 1, Educational Award Committee Meeting, Parlor "D"
2:00 P.M.—Missiles and Rockets Welded Fabrication Open Panel, Windsor Ballroom
2:00 P.M.—Manufacturers' Committee Meeting, Parlors "B" and "C"
2:00 P.M.—Section Officers' Meeting, Windsor Court
6:30 P.M.—WRC University Research Dinner, Windsor Court
8:00 P.M.—WRC University Research Conference, Windsor Terrace

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April 19th, Thursday

8:00 A.M.—Authors' Breakfast, Parlor "C"
8:00 A.M.—District No. 2, Breakfast Meeting, Parlor "D"
9:00 A.M.—AIEE Electric Welding Committee Meeting, Parlor "F"
10:00 A.M.—Board of Directors Meeting, Parlor "B"
12:30 P.M.—Board of Directors Luncheon, Parlor "C"

PLANT TOURS

•Tuesday, April 18th

Tours A-1 and A-2: Worthington Corp., Harrison, N. J.—Buick, Oldsmobile, Pontiac General Motors Assembly Plant, Linden, N. J.

Schedule: A-1	
Leave Commodore Hotel by bus for Worthington	8:30 A.M.
Lunch at Golden Lantern Restaurant, Linden, N. J.	12:00 Noon
Arrive at General Motors	1:15 P.M.
Arrive Commodore Hotel	5:30 P.M.

Schedule: A-2	
Leave Commodore Hotel by bus for General Motors	8:30 A.M.
Lunch at Golden Lantern Restaurant, Linden, N. J.	11:30 A.M.
Arrive at Worthington	1:30 P.M.
Arrive Commodore Hotel	5:30 P.M.

Price: $5.50 per person

Includes 2 plants, lunch and transportation

Tours B-1 and B-2: Linde Co. Development Lab, Newark, N. J.—International Nickel Co. Research Lab and Electrode Production Plant, Bayonne, N. J.

Schedule: B-1	
Leave Commodore Hotel by bus for Linde	8:30 A.M.
Lunch free at Linde	12:20 P.M.
Leave for Inco	1:00 P.M.
Arrive Commodore Hotel	5:30 P.M.

Schedule: B-2	
Leave Commodore Hotel by bus for Inco	8:30 A.M.
Lunch free at Linde	1:10 P.M.
Arrive Commodore Hotel	5:30 P.M.

Price: $2.50 per person

Includes 2 plants and transportation, lunch free

•Wednesday April 19th

Tours C-1 and C-2: (For AWS members) Repeat of Tour A

Tours D-1 and D-2: (Principally for IIW members) Repeat of Tour B

•Thursday April 20th

Tour E: (U. S. citizens only) Republic Aviation Corp., Farmingdale, N. Y.—Grumman Aircraft Engineering Corp., Bethpage, N. Y.

Schedule:	
Leave Commodore Hotel by bus for Republic	8:00 A.M.
Lunch at Republic	11:30 A.M.
Arrive at Grumman	1:00 P.M.
Arrive at Commodore Hotel	5:00 P.M.

Price: $5.00 per person

Includes 2 plants, lunch and transportation

LADIES' PROGRAM

April 17th, Monday

9:00 A.M.	Coffee Hour, Windsor Terrace, Commodore Hotel
10:00 A.M.	Optional: Empire State Building Shopping United Nations Building Tour
11:45 A.M.	Individual Luncheons in UN Delegates Dining Room
1:30 P.M.	Optional: United Nations Building Tour Shopping Empire State Building
6:00 P.M.	Reception for all AWS and IIW participants
8:00 P.M.	Banquet for all AWS and IIW participants

April 18th, Tuesday

9:00 A.M.	Breakfast and Fashion Show at B. Altman & Co., Charleston Garden Restaurant
	Optional: Museums, Planetarium, Shopping, Helicopter Trip

April 19th, Wednesday

9:00 A.M.	Coffee Hour, Windsor Terrace, Commodore Hotel
10:00 A.M.	Radio City Music Hall (Entertainment)
1:00 P.M.	Individual Luncheons
2:00 P.M.	Optional: Theater Matinee Rockefeller Center Tour RCA-NBC Television Studio Tour

April 20th, Thursday

9:00 A.M.	Coffee Hour, Windsor Terrace, Commodore Hotel
10:00 A.M.	Optional: Flower and Fish Markets, Stock Exchange, Shopping Circle Tour of Manhattan

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• AWS members and their guests are invited to attend the traditional President's Reception which will be held in the Windsor Ballroom of the Commodore Hotel at 6:00 P.M. on Monday evening, April 17th. Those who attend will have an opportunity to meet President "Dave" Thomas and President-elect "Al" Chouinard, as well as other national officers.

• At 8:00 P.M., on the same evening, the Annual Banquet will take place in the Commodore Hotel's Grand Ballroom. Tickets for this affair will be on sale at the hotel at $12 per person.

• The Society has arranged for professional entertainment and an international speaker to highlight the banquet.

HIGHLIGHTS OF EXHIBITS

AT 1961 WELDING SHOW

COLISEUM
NEW YORK, N.Y.

APRIL 18-20

Air Reduction Sales Co. Booths 320, 321

Airco will exhibit a new, compact and inexpensive Heliweld (gas tungsten-arc welding) head. The Model "D" electronic edge tracer and the Model "J" line tracer; and a new mild steel welding wire will be demonstrated. The Airco Special Products Dept. will introduce its new balanced-wave Heliweld package and a stake-seamer and welding positioner unit. Aircospray and Fluxcor Aircosil 45 silver brazing wire will be demonstrated live.

Airline Welding & Engineering Booth 706

First showing of combination machine that accurately slits and turns up precise standing edge of foil material (0.001 to 0.015 in.). Also demonstrating 48-in. longitudinal fixture butt welding 0.005-in. stainless steel and other materials.

Alloy Rods Co. Booth 601

All-State Welding Alloys Co., Inc. Booth 529

Mirror finish aluminum wire for MIG and TIG welding, also silicon bronze, deoxidized copper, aluminum bronze and phosphor bronze. Most advanced aluminum electrode with extruded coating, Smoothcote #34. Solders with temperature ranges of 400 to 800° F. Continuous cast iron welding process.

Alphil Spot Welder Mfg. Corp. Booth 717

Alphil will exhibit a new Multi-Head Spot Welder, and an Air-Operated Bench Welder.

Aluminum Co. of America Booth 631

Alcoa will have an operating exhibit staffed by experts in all phases of joining aluminum. Active joining demonstrations will include "Heliarc Cutting" of aluminum, consumable electrode and tungsten inert-gas arc welding, torch brazing and soldering of aluminum with both low-temperature and high-temperature solders.

The largest production ultrasonic spot welder ever built will be featured.

American Brazing Alloys Corp. Booth 630

American Brazing Alloys will exhibit a complete line of brazing alloys made in the U. S. This line includes such alloys as low-fuming bronze, nickel silver phos-sil alloys, silver solder and aluminum welding wire.

American Machine & Foundry Co., Research & Development Div. Booth 209

A demonstration of its friction welding process. Engineers will show various combinations of materials such as brass, aluminum, steel and plastics to discuss specific applications. Two laboratory machines, in addition to literature, will also be displayed.

American Pullmax Co., Inc. Booth 200

The latest method developed for Beveling Heavy Plate prior to welding will be shown. Known as the Pullmax X-8 Beveler, this amazing machine bevels plate at the rate of 11 fpm over conventional methods of 11 ipm.

Aro Spot Welder Corp. Booth 612

Aro will exhibit a complete line of portable spot welders and timers, including hand and air-operated guns with or without water-cooling, various twin-spot (series) welders and "Arval" spring balancers.

Arcair Co. Booth 727

The Arcair metal removal process will be demonstrated throughout the entire show. All models of Arcair torches and electrodes will be on display. New products include heavy duty automatic and semiautomatic equipment.

Arcos Corp. Booth 521

Welding demonstrations of Arcos stainless, nickel alloy, low alloy, aluminum, hard surfacing filler metals; automatic vertical electroslag and electrogas, and semiautomatic CO_2 welding with flux-cored mild-steel electrodes.

Aronson Machine Co., Inc. Booth 700

Aronson Machine Co. will exhibit representative models from the Welding Positioner and Turning Roll lines including new accessories such as the W-O-R-M Ground attachment and IPM Tachometer for

To: Editor of Welding Journal
33 W. 39th St., New York 18, N. Y.

I regret that I am unable to attend this year's AWS 42nd Annual Meeting and Exposition in New York.

Would you please forward me information on the following exhibits?

Booth numbers.....

Name.....

Address.....

Company Affiliation.....

variable diameters to facilitate latest welding processes.

Balteau Electric Corp. Booth 328

The most portable industrial X-ray units, newest Baltospot 150 with wide angle (60-deg) directional beam or 360-deg beam (Panoram-X) and the most versatile Baltogrape 300 Directional beam or 360-deg beam (Panoram-X). X-ray head weighs only 136 lb.

Bay State Abrasive Products Co. Booth 501

Will feature by demonstration a new "U" grade series of Koolie Hat weld grinding and cutting reinforced disk-wheels, which offer easier operation, extra safety, more uniform speed, longer life on all materials.

Bernard Welding Equipment Co. Booth 220

An actual demonstration showing the simplicity of attaching and the secureness of the new Bernard Welding Cable Connectors. Also a display of Shortstub Electrode Holders and the Bernard water coolers for MIG and TIG welding.

Bren Weld Corp. Booth 400

In addition to its line of arc spot weld guns, the Bren Weld Corp. will exhibit two new welding machines. A 125-amp budget-priced utility welder and a 180-amp welder. Both units feature one-piece molded fiberglass cases.

Brunmar Commercial Corp. Booth 110

A. E. G. Universal Angle Grinders, equispeed with 2-hp heavy-duty motor for connection with single-phase a-c 110 v, designed for speeds up to 8000 rpm on their 7-in. models and 6600 rpm on their 9-in. models. Ipaflex Fibre Glass Reinforced Depressed Center and Cutoff Wheels for roughing off and smoothing welds as well as all cut-off operations. These wheels are approved for the high speeds of the A. E. G. Angle Grinders.

Cam-Lok Division, Empire Products, Inc. Booth 221

Exhibiting all types of cable connectors, plugs and receptacles, including waterproof connectors for cable sizes from 760 MCM down to #18 wire. New explosionproof plugs, receptacles and distribution blocks. Electrode holders. Cable splicing and repair kits.

Coast Metals, Inc. Booth 202

Coast Metals will display a braze torch for overlay work and production brazing using powdered-metal alloys, and other products including hard facing welding rods, wire, brazing powders and castings for heat, wear and corrosion resistance.

Cosa Corp. Booth 300

Trumpf Universal Sheet Metal machines, showing copy nibbling, deformation-free slotting, clamping of the sheet and coordinate systems with scales on the machine. It has 6 speeds, stroke adjustment 0–$^{13}/_{32}$ and oil and air cooling for tools.

Coyne Cylinder Co. Booth 228

A showing of their all new Coyne 1000 cu ft capacity acetylene cylinder. They will also show their complete line of Coyne 92 marked acetylene cylinders.

Dockson Corp. Booth 703

A display of oxyacetylene welding torches, cutting torches, regulators, CO_2 regulators, welders' helmets and goggles, and the new Chiporweld goggle.

Earth Equipment Corp. Booth 707

Gloor expeditor steel flame cutting machine, made in Switzerland, will be introduced.

Emerson Electric Mfg. Co. Booth 713

TIG weld 295—new AC 295-amp welder—designed for both stick electrode and inert gas welding processes will be featured. Other a-c units in the line will also be shown.

Engelhard Industries, Inc. Booth 712

American Platinum & Silver Div. will exhibit brazing alloys and fluxes: silver, gold, palladium and nicrobraz alloys together with fluxes, stop-off and cement.

Eutectic Welding Alloys Corp. Booths 134, 134-A

Eutectic will display a flux-coated, silver-brazing-type alloy, said to cut brazing time by two-thirds through elimination of a separate flux.

Exomet, Inc. Booth 124

Exomet will exhibit Exoweld, a thermit welding for rail and rebar; and Exo-Annéal, an exothermic method for preheat and postheat treatment of pipe weldments.

Fairchild Publications Booth 234

Metalworking News, a business newspaper, published weekly for the metalworking industry will be exhibited at the Fairchild booth. Complimentary copies of the April 17th issue will be distributed.

Falstrom Co. Booth 711

Introduction of the new Falstrom Controlled Angle Torch for tungsten inert gas, arc welding. The water-cooled Model WC-180 will be shown with welding samples and illustrations.

Fenway Machine Co. Booth 131

Fibre-Metal Products Co. Booth 616

A new, improved No. 3-C Headgear for welding helmets, new No. 3-Q Quick-lok headgear for welding helmets, goggles and face shields, and other products including Supergrip, electrode holders and ground clamps, welding helmets and safety cap combinations.

Flood Safety Products Co. Booth 109

New welding accessories will be exhibited by Flood.

Frommelt Industries, Inc. Booth 117

A portable, self-standing floor screen, Porto Screen "50" and Saf-T-Screen "60" will be exhibited. Also on display will be a Spa-Fla safety wrap-around shield with built-in handy hanger. Frommelt will show their Weld-Tex vinyl-coated glass cloth fabric and Ray Foil protective heat cloth.

General Electric Co. Booth 404

A family of coaxial ignitrons for standard welding service will be exhibited. The GL-7669, GL-7671 and GL-7673 feature a coaxial cathode termination which enables the tube to control high-current, short-termination pulses without damage from magnetic defects. Standard welding ignitrons with a new anode lead will also be shown.

Glendale Optical Co., Inc. Booth 507

A new "Unisite" welding goggle featuring single plate vision, soft construction and a welding magnifier holder will be shown.

Hamilton Electrona, Inc. Booth 231

Applications of electron beam welding. High-voltage, high-energy density electron beam welding produces depth to width ratios up to 20:1, making possible welding geometries and applications heretofore impossible.

Hancock-Gross Mfg., Inc. Booth 229

A full line of single-line as well as twin-line welding hoses, ferrules for welding hoses and other types of ferrules and fittings will be exhibited.

Handy and Harman, Inc. Booth 312

Harnischfeger Corp. Booth 617

Exhibited will be the P&H line of welders and electrodes including its latest addition, a 200 amp engine driven DC welder that delivers 3½ kw, 120 volts ac, 60 cycle current for lighting and electric tools.

Harper Trucks, Inc. Booth 629

A complete line of all-welded-construction welding cylinder and medical oxygen trucks, featuring the 900 series heavy duty truck. Rolls on automobile tires, can be towed and hoisted. New 16-gage heavy duty tool boxes.

Harris Calorific Co. Booth 634

An animated torch display: new 29 Single-State and the 77 Multi-Stage Gageless Regulators; expanded line of metering regulators; new XX-87 High Delivery Pressure (0–2500 lb) Regulator; new outfit with "O" ring seals.

Hobart Bros. Booth 315

Automatic and Semiautomatic Arc Welding Equipment will be exhibited, featuring new Micro-Wire Package for all-position welding with small wires. Live demonstrations on gage thickness metal with wide joint gaps will be frequently presented.

Huntington Alloy Products Div., International Nickel Co., Inc. Booth 217

Exhibit will feature two recently-developed Inconel alloy welding materials that are claimed to meet the rigid standards set for nuclear applications.

Independent Engineering Co., Inc. Booth 602

Display will feature IECO acetylene cylinders with pictorial highlights of the cylinder manufacturing process. The remainder of the display will feature pictures of IECO package type oxygen-nitrogen plants, argon equipment, acetylene generators and semitrailer gas transports.

Kaiser Aluminum & Chemical Corp. Booth 705

A display of a line of copper and aluminum welding cables.

KSM Products, Inc. Booth 433

KSM will display a new portable "CD" capacitor discharge stud welding unit, the lightweight Bantam stud welder and the Mark XI stud welder, power pack rectifier in a live demonstration.

Lenco, Inc. Booth 113

Lenco will display a screw-type 400 amp electrode holder, a 500 amp economy ground clamp, a hi-amp electrode holder, ground attachments and cable terminals.

Lennox Tool and Machine Builders Booth 128

A Model TE-250 machine will be demonstrated as the latest addition to the Lennox Tru-edge line of Metlmastr shearing, forming and piercing equipment.

Lincoln Electric Co. Booths 520, 524

A new semiautomatic production welder for use on both machinery and structural fabrication will be exhibited. The innershield Squirt Welder continuously feeds a tubular, self-shielding electrode through a welding gun that is manually supported and guided along the joint being welded.

Linde Co., Div. of Union Carbide Corp. Booth 421

Linde's arc welding exhibit will include a demonstration of Plasmarc Cutting, and will feature the introduction of two new plasma arc processes, Plasmarc Welding and Plasmarc Weld Surfacing with line demonstrations.

Liquid Carbonic Div., General Dynamics Booth 304

Live demonstrations of the Liquidweld line of welding and cutting equipment including a new machine cutting torch of exclusive design and a portable cutting machine.

Magnaflux Corp. Booth 715

A variety of testing and measuring equipment will be exhibited. Included will be magnetic particle testing units, for crack detection; dye penetrant and fluorescent penetrant methods for crack and leak detection in welded tanks and vessels; eddy current instruments for weld crack detection and metallurgical analysis; and a thermographic method for determining integrity of spot welds and brazing structures.

Marindus Co. Booth 709

A display of Von Ax Air Gun—Scaling tool with "intelligence," and Von Ax Cleaner-Oiler—a device for maintenance of pneumatic tools of every description.

Markal Co. Booth 625

Markal will demonstrate its new Thermomelt temperature indicator stick. The outstanding feature of Thermomelt is the new combination holder-dispenser.

Marquette Mfg. Co., Div. of Marquette Corp. Booth 714

Martin Wells, Inc. Booth 117

McKay Co. Booth 222

A complete line of stainless steel, mild steel, low-hydrogen and hard-surfacing welding electrodes and automatic wires. Live demonstrations of these products will be featured.

Automatic Welding Co., a subsidiary of The McKay Co. will display one of its Automatic Welding Machines used for rebuilding all types of construction, mining and general industrial equipment. Live demonstrations will be featured.

Messer Cutting Machines, Inc. Booth 504

Messer will introduce a newly designed stationary flame-cutting machine with electronic steering. Highlights of the display will be continuous live cutting demonstration and a graphic exhibition emphasizing the wide variety of machines offered by Messer.

Metal & Thermit Corp. Booth 619

A display of their expanded line of M&T-Murex Welding Machines. Also featured will be more than 1000 types and sizes of Murex electrodes as well as welding accessories.

Metallizing Co. of America, Inc. Booth 126

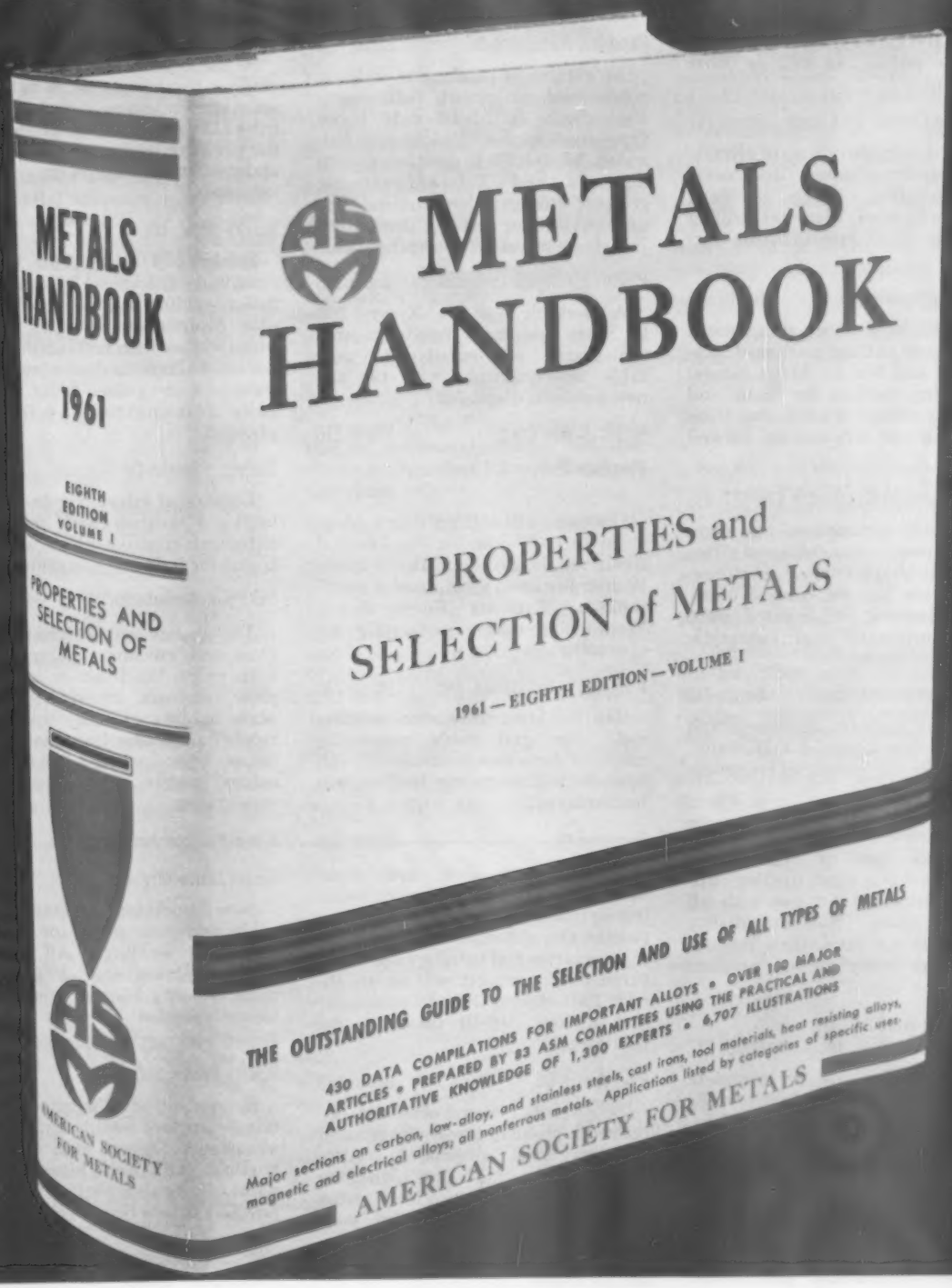
Showing of latest models of Mogul metallizing equipment—Mogul Turbo-Jet and Mogulectric metallizing guns. Mogul Type R-2¼ in. Rokide Rod Spraying Unit. Mogul Powder Jet 2 in 1 Combination all-purpose metal powder and ceramic spraying equipment. Mogul metallizing accessories, equipment and supplies.

Metals for Industry, Inc. Booth 106

Tin-A-Lum, a new low-temperature fluxless solder, developed for use on aluminum and other alloys will be demonstrated.

Metco, Inc. Booth 536

A complete line of flame spray equipment, including a new advanced prototype Plasma Spray Head, will be exhibited.


METALS HANDBOOK
1961
EIGHTH EDITION VOLUME I
PROPERTIES AND SELECTION OF METALS
AMERICAN SOCIETY FOR METALS
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THE OUTSTANDING GUIDE TO THE SELECTION AND USE OF ALL TYPES OF METALS
430 DATA COMPILATIONS FOR IMPORTANT ALLOYS • OVER 100 MAJOR ARTICLES • PREPARED BY 83 ASM COMMITTEES USING THE PRACTICAL AND AUTHORITATIVE KNOWLEDGE OF 1,300 EXPERTS • 6,707 ILLUSTRATIONS
Major sections on carbon, low-alloy, and stainless steels, cast irons, tool materials, heat resisting alloys, magnetic and electrical alloys; all nonferrous metals. Applications listed by categories of specific uses.
AMERICAN SOCIETY FOR METALS

For details, circle No. 12 on Reader Information Card

Mid-States Welder Mfg. Co. Booth 233

Miller Electric Mfg. Co., Inc. Booth 509

Miller will demonstrate new products including Model SCP-200 single-phase constant potential d-c welder, Model CP-3VS three-phase constant potential d-c welder, Model BWC-300-MAP balanced-wave a-c welder, as well as other equipment.

Milwaukee Electric Tool Corp. Booth 201

An all heavy-duty line of electric drills, sander-grinders, hacksaws, aerial grinders, bench grinders, shears, hole saws, diamond drilling equipment and metal-cutting circular saw.

Modern Engineering Co. Booth 600

An exhibit of Meco professional welding and cutting packaged outfits No. 1 and No. 2. Meco natural gas cutting torches for hand and machine cutting. Free instructions for cutting with city natural gas and LP gases.

National Cylinder Gas Booths 436, 437, 439

NCG will demonstrate two completely new, transistorized line tracers for shape cutting machines. Also, a new line of control units, wire dispensers and related guns for semiautomatic and automatic welding processes.

National Electronics, Inc. Booth 119

A line of ignitron, thyratron and rectifier tubes designed and manufactured for the industrial electronic control industry.

National Torch Tip Co. Booth 336

Complete line of replacement cutting, welding and heating tips for all equipment for use with all types fuel gases. New top quality line of gas air appliances for use with either acetylene or propane gases.

Nelson Stud Welding Div.,
Gregory Industries, Inc. Booth 237

Demonstration of a complete range of stud welding with studs from 0.093-in. diam to 0.750-in. diam to base plates from 26 gage to 1/2 in. thick. Latest advancements in aluminum and welding will also be shown.

Omark Industries, Inc. Booth 301

Gramweld portable and bench stud welding machines will be displayed and demonstrated by Omark Industries, Inc. The portable units are for construction and shipyard applications.

Page Steel & Wire Div.,
American Chain & Cable Co., Inc.
Booth 402

A new color-coding system for quick identification of the various grades of Page automatic welding wire will be exhibited.

Pandjiris Weldment Co. Booth 420

An exhibit of production welding positioning equipment, featuring a 1961 model RBM 16 x 16 boom type manipulator; precisioned balanced Model 30-6 positioner with dial-weld and T-J self-centering gripper; thin gage longitudinal type external seamer and the new Pandjiris single wheel drive turning rolls.

Philips Electronic Instruments Booth 213

A portable 140 kv X-ray, 200 kv X-ray equipment, besides gamma radiographic equipment and a portable spectrograph will be the new products displayed.

Picker X-Ray Corp. Booth 216

Precision Welder & Flexopress Corp.
Booth 726

Precision will exhibit a new Magnetic Force Welder for Vinyl coated steel; a large Foil Butt Seam Welder for sheet steel; and a small tandem Magnetic Force Bench Welder for dissimilar metals—all operating.

J. M. Ragle Industries, Inc. Booth 230

Tip drill kits, white metal welding rod, hose and cable measuring machine, hose ferrule crimper, torch lighters and soapstone holders will be displayed.

Ransome Co. Booth 305

Exhibit will show and demonstrate packaged automation welding equipment consisting of welding positioners, automatic welding head manipulators and turning rolls. Featured in the exhibit will be an all-new 1961 design 3000-lb positioner and a new 100-lb bench model positioner.

Reid-Avery Co. Booth 525

Booth will feature new and improved high-alloy low-hydrogen and stainless steel electrodes. Also, Super Lustre finish for high-alloy automatic wire, composite stranded wire for custom-made alloy submerged welding and a new single-pass, double-layer automatic head will be shown.

Rexarc, Inc. Booth 401

Robotron Corp. Booth 212

A new precision cascade counting resistance welding timer will be displayed. The timer incorporates transistors mounted on plug-in printed circuit boards. Features include tap switch weld time, integral heat control and delayed firing.

Robvon Backing Ring Co. Booth 232

A display of backing rings including commercial split rings, offset rings for joining differing pipe or tube ID's and finely-machined rings for pressure piping in carbon steel, stainless steels, aluminum and other materials.

Sciaky Bros., Inc. Booth 729

Sciaky will exhibit, for the first time, fully-automatic TIG and MIG fusion welding equipment with modular component concept, electron beam welder with rectangular chamber and combined control bench welder with pulse firing control. Live demonstrations for each planned.

Secheron Works Co. Booth 203

Display of latest compact design inert-gas welders with fully-static automatic controls, also coated electrodes for special applications.

Sellstrom Manufacturing Co. Booth 638

The display will feature new fibre glass and vulcanized fibre helmets with nylon lift front or stationary plate retainers, having extra large plate holding capacity and plastic ratchet adjusting headgear. Other items will include welding and safety goggles, face shields and respirators.

Simonds Abrasive Co. Booth 208

Singer Glove Mfg. Co. Booth 101

New buckskin welder's glove, cable and hose protector for MIG and TIG welding. All types of welder's gloves and clothing, portable welding booths, welding curtains, asbestos blankets and curtains.

Sperry Products Co. Booth 718

Sperry will exhibit three types of nondestructive testing equipment—ultrasonic, X-ray and magnetic particle. Of special interest will be a line of magnetic particle inspection powders in new bright colors.

Square D Co. Booth 505

Norpak static welding control will be featured by the Square D Co. This transistorized welder control provides greater accuracy, smaller size and eliminates tube filaments.

Stoody Co. Booth 424

Exhibit will introduce automatic welding systems featuring the Crushermatic, a machine that automatically rebuilds and hard-faces crusher rolls in position. Also other new hard-facing procedures.

Sylvania Electric Products, Inc. Booth 114

A line of tungsten welding electrodes will be exhibited.

Tec Torch Co., Inc. Booth 316

An improved line of "Visuweld" torches, and Tec spot welding products. Featured will be the new Tec "Tiny Giant"—the smallest 300 amp 45 deg or 90-deg angle torch. All products will be demonstrated.

Tempil° Corp. Booth 528

Tempilstiks° for 2050, 2150, 2350 and 2450° F will be presented for the first time.

Toyomenka, Inc. Booth 537

Tweco Products, Inc. Booth 627

A high pressure ball-point mechanical cable connection now on all Tweco electrode holders, ground clamps, cable connectors, cable splicers and cable lugs. New double ball-point cable connection on heavy duty holders designed to use iron powder electrodes.

Uniflex Cable Div., Gar Wood Industries Booth 108

Exhibit will include a complete line of resistance welding cables and secondary connectors. New items to be shown are quick change adaptors and terminals and a new alternate polarity air-cooled cable.

Unique Equipment, Inc. Booth 514

A display of manipulators, positioners, turning rolls and special equipment that offers greater accuracy and less maintenance for the most intricate type of welding.

Vickers Inc., Booth 728

Controlarc a-c, d-c welder with 3-phase d-c rectifier welders, plus slope controllers, inertia-gas welding controls and a complete line of accessories will be presented.

Victor Equipment Co. Electric Products Div. Booth 604

Victor will exhibit flame-cutting and welding equipment; hardfacing alloy rods; automatic rebuilding equipment and machinery and a liquid fuel safety torch.

Wall Colmonoy Corp. Booth 236

A new Model F Spraywelder and two experimental alloys will be shown for the first time at the Wall Colmonoy exhibit.

Welding Alloys Mfg. Corp. Booth 111

Welding Design & Fabrication Booth 116

Copies of special Welding Show issue of Welding Design & Fabrication magazine will be distributed and a display of 920-page 1960–61 Welding Data Book and information on forthcoming 1962–63 edition. Editors will be present.

Weld Tooling Corp. Booth 739

Weld Tooling will exhibit Bug-o which carries a gas cutting torch at accurate speeds vertical, horizontal, overhead and flat Hob-o which cuts and bevels accurate holes fast in any position and Con-o which cuts and bevels saddles with extreme accuracy.

Welduction Corp. Booth 104

Welduction will exhibit a new concept in arc welders. It is a completely-sealed cabinet, water cooled rectifiers and transformers.

Welsh Manufacturing Co. Booth 533

Completely new "Warrior" welding helmets including standard fronts, lift fronts and handshields will be displayed. Also new "Welshman" positive stop faceshields and new wrap around faceshields.

Weltronic Co. Booth 609

A new control for automatic welding devised by Weltronic will be displayed.

WESPO Div., Vlier Engineering Corp. Booth 132

Exhibit will feature toggle clamps and pliers designed to hold individual components of a weldment securely in place during the tacking and/or welding operation.

Westinghouse Electric Corp. Booth 333

Wheelabrator Corp. Booth 613

Demonstration of how Wheelabrator blast cleaning results in faster, better quality welding and on finished weldments provides lower cost, more effective removal of scale, flux, and spatter, and a surface to which paint will adhere tenaciously.

Survey Results . . .

1. Read Welding Journal regularly.....98%
2. Find Journal contents helpful..... 98%
3. Read ads in Journal..... 87%
4. Have Bought Products As Result of Reading Welding Journal.....49%(!)
5. Have investigated new processes on basis of ads in Journal..... 71%

SECTION NEWS AND EVENTS

As reported to Catherine M. O'Leary

Alabama

COVERED ELECTRODES

Birmingham—Harry F. Reid, Jr., manager of the Technical Service Div., McKay Co., York, Pa., gave a talk entitled "It Isn't Mud" at the February 14th meeting of the *Birmingham* Section held at Salem's Restaurant Number Two. His subject covered a very thorough discussion of electrode coatings. The "What?," "Why?," and "How?" of electrode coatings were answered; the talk was illustrated by a series of charts showing the compositions of the various electrodes.

STEEL CONSTRUCTION JOINTS

Mobile—Van Rensselaer P. Saxe, consulting engineer of Baltimore, Md., and the originator of the "Saxe Erection Clips" was the guest speaker at the January 17th meeting of the *Mobile* Section. The dinner and technical meeting were held at the State Vocational Trade School.

Mr. Saxe explained various methods of designing construction joints of steel members in buildings. He pointed out the excess shop work involved in shop handling of the steel, punching holes, riveting connections and bolting the temporary connections of structures to be riveted or erected with temporary bolts.

The most economical method of erection considering a fully welded structural steel building as compared to a riveted structure, concrete structure or a structure using bolts for a temporary erection method was the main topic of discussion which followed the lecture.

Excellent color slides were shown to mold all the discussion into a composite picture.

California

WELDING MANAGEMENT

Los Angeles—The January meeting of the *Los Angeles* Section featured a four-man panel discussion on the subject of "Management's Viewpoint on the Welding Industry."

The meeting was held January 19th at the Rodger Young Auditorium with approximately 85 members and guests in attendance. Those members fortunate enough to be at this meeting will long remem-

SECTION MEETING CALENDAR

MAY 2

TULSA Section. Danner's Cafeteria, Tulsa, Okla. Installation of Officers.

MAY 3

SUSQUEHANNA VALLEY Section. Foot Hills Manor, Shickshinny, Pa. "Electroslag Welding," Walter H. Wooding, Arcos Corp.

MAY 5

CLEVELAND Section. 22nd Annual Symposium. "How to Choose and Use the Semi-automatic Welding Processes." Hotel Manger. 2:00 p.m.

MAY 6

LEHIGH VALLEY Section. Ladies' Night.

MARYLAND Section. Engineers Club, Baltimore. Dinner 6:30. Meeting 8:00. Ladies' Night. Dinner and Dance.

MAY 8

BOSTON Section. Hotel Bostonian. Dinner 6:00 P.M. "Plasma Cutting, Its Uses and Applications," George A. Klasson, Thermal Dynamics Corp.

MAY 9

DAYTON Section. Plant Visit.

NORTHWEST Section. Minneapolis, Minn. Annual Meeting—Election of Officers.

SANGAMON VALLEY Section. Decatur, Ill. "New Cast Iron Welding Procedure," L. D. Richardson, Eutectic Welding Alloys Corp.

WESTERN MASSACHUSETTS Section. Oaks Inn, Springfield, Mass. Dinner 6:30. Technical Session 8:00. "Iron Powder Electrodes, Pro and Con," Wayne L. Wilcox, Arcos Corp.

MAY 11

IOWA-ILLINOIS Section. Highland Park Bowl, Moline, Ill. Dinner 6:30. Meeting 7:30. "Gas Shielded Welding."

J.A.K. Section. Kankakee, Ill. "Principles of Shrinkage and Distortion and Design," LaMotte Grover, Air Reduction Co.

ST. LOUIS Section. Ruggeri's Restaurant. "Welding or Joining of Exotic Metal," Jay Bland, G. E. Atomic Power Lab.

ALBUQUERQUE Section. 7:30 P.M. Installation of Officers.

MAY 12

TOLEDO Section. Dinner Dance and Installation of Officers.

MAY 13

COLUMBUS Section. Lincoln Lodge. Ladies' Night.

MADISON Section. Social.

SAGINAW VALLEY Section. Green Acres Golf Club, Bridgeport, Mich. Golf Stag.

MAY 16

NORTHWESTERN PENNSYLVANIA Section. Annual Business Meeting and Ladies' Night.

OLEAN-BRADFORD Section. Castle Restaurant, Olean, N. Y. Dinner 7:00. Meeting 8:30. "Stud Welding Story," R. C. Friedly, Nelson Stud Welding Div., Gregory Industries, Inc.

MAY 17

SOUTH FLORIDA Section. "Defense Performed by Our Telephone Company," Southern Bell Telephone Co.

MAY 18

BATON ROUGE Section. "Advances in Welding in Europe and Russia," C. E. Jackson, Linde Co.

IOWA Section. Stag.

MAY 20

DETROIT Section. Annual Ladies Nite Party. Latin Quarter. 6:30 p.m.

MAHONING VALLEY Section. Victoria Restaurant, Youngstown, Ohio. Dinner 7:00. Meeting 8:00. Seventh Annual Ladies' Night.

NEW JERSEY Section. Annual Dinner Dance. Essex House, Newark, N.J.

PHILADELPHIA Section. Annual Dinner Dance. Treadway Inn, St. Davids, Pa.

MAY 25

NIAGARA FRONTIER Section. The Cypress, Buffalo, N. Y. "Industrial Radiography—A Nondestructive Testing Tool of Quality Control," William D. Kiehle, Eastman Kodak.

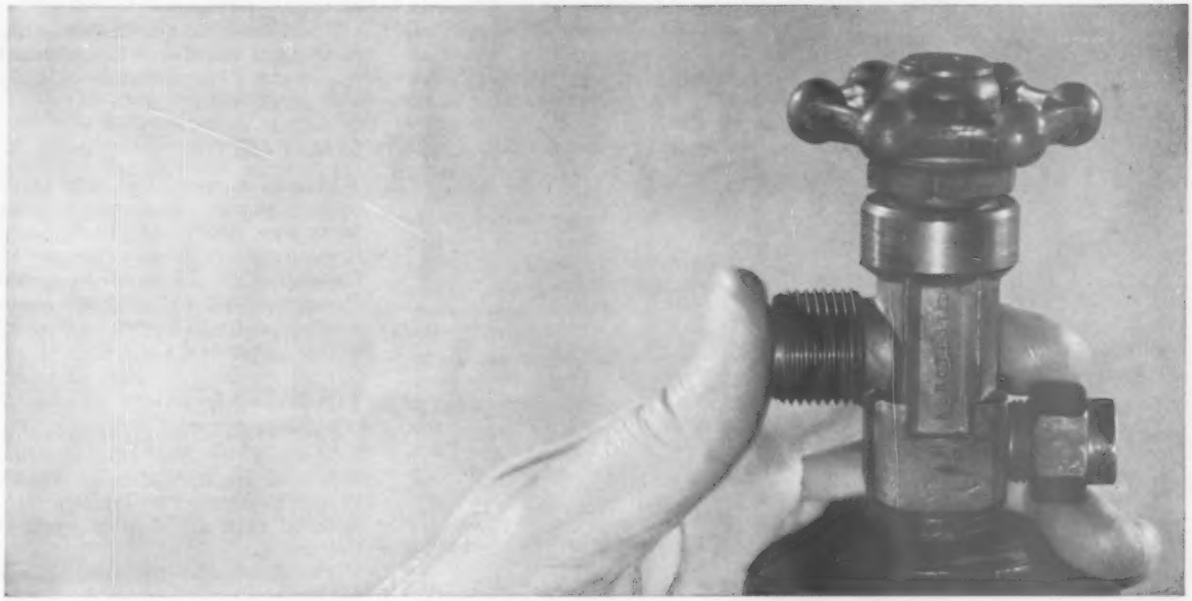
MAY 26

INDIANA Section. Buckley's, Cumberland, Ind. "Resistance Welding," J. B. Welsh, Cutler-Hammer.

MAY 27

FOX VALLEY Section. Appleton Elks Club, Appleton, Wis. 6:00 P.M. Annual Spring Dinner-Dance and Installation of Officers.

Editor's Note: Notices for July 1961 meetings must reach JOURNAL office prior to April 20th, so that they may be published in the June Calendar. Give full information concerning time, place, topic and speaker for each meeting.



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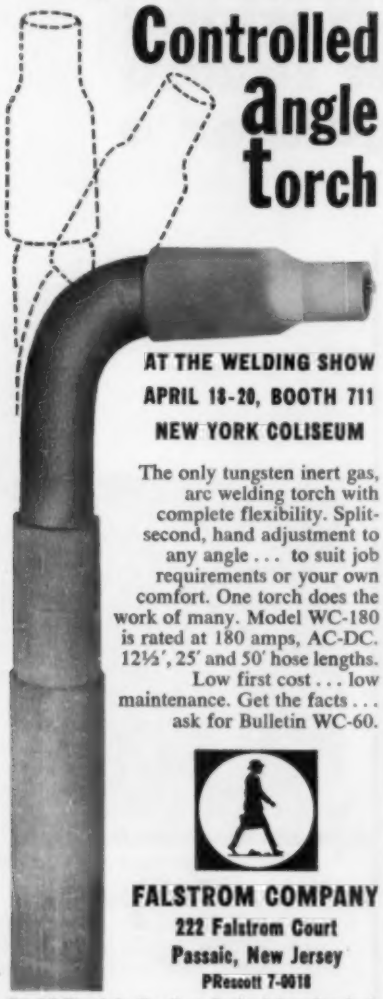

AT THE WELDING SHOW
APRIL 18-20, BOOTH 711
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The only tungsten inert gas, arc welding torch with complete flexibility. Split-second, hand adjustment to any angle . . . to suit job requirements or your own comfort. One torch does the work of many. Model WC-180 is rated at 180 amps, AC-DC. 12½', 25' and 50' hose lengths. Low first cost . . . low maintenance. Get the facts . . . ask for Bulletin WC-60.

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ber this program as one of the best panel discussions held for some time.

Men of management in the welding industry were selected to present opinions and answers in all phases of welding and welding processes as applicable to their particular type of industry, covering such items as: on-the-job training, the importance of a welder and his knowledge of the various processes, the welding engineer and his company value, utilization of the engineer as a technician vs. his proper classification as engineer, their availability and a need for more such men in industry. The panel included Charles Concannon, sales manager of Abasco, Inc., acting as moderator, and J. V. Banks, assistant general manager for Kaiser Steel, Fabricating Div., whose discussion covered the problems encountered in and the value of welding in the structural steel industry.

W. F. Nash, Jr., assistant manager of operations for the C. F. Braun Co., discussed the importance of welding and its allied processes in industry and the need for welding engineers and technicians who are required to exercise the control of the quality desired. F. H. Walters, general superintendent of experimental manufacturing for Rocketdyne, Div. of North American Aviation, discussed the many difficulties encountered in his type of industry and the importance of on-the-job training that is required to keep abreast of the many new processes in welding and allied processes required in the missile and space program. The discussions covering all types of welding and its allied processes were well appreciated and greatly enjoyed by all those present.

Upon conclusion of the program, each panel member was presented with a gift in appreciation of a job well done.

STAG PARTY

Lemon Grove—The *San Diego* Section dinner meeting and stag party were held at the El Morocco Restaurant in Lemon Grove on December 7th. A social hour and dinner were followed with entertainment by a group known as Sammy Bongo Carise and Co.

STAINLESS STEEL

San Diego—The regular monthly meeting of the *San Diego* Section was held at the Midway Chuck Wagon Restaurant on January 18th. A social hour and dinner preceded the meeting.

The speaker at the meeting was D. W. McDowell, Jr., of the International Nickel Co., Inc. Mr. McDowell gave a very interesting talk on "Welding of Stainless Steel." Slides were used to illustrate the talk, and a question-and-answer period followed.

STRESS RELIEVER

Oakland—Over sixty members of the *San Francisco* Section attended the January 23rd dinner meeting held at Plands in Oakland. "Post Heat Treatment of Field Weldments" was the subject of a talk by Lynn Christensen of the Chicago Bridge & Iron Co., Chicago, Ill. Mr. Christensen described various methods used for stress relieving large field-welded tanks and other structures.

ICE CREAM WAS THE WINNER

As it so often happens, Barney Faas, San Francisco Section Chairman, has the floor but the dessert is claiming most attention at the January 23rd meeting. Seated in front of Faas is Charlie Robinson, District 10 director, and to his left are: Fred Stettner, Bill Ajello, Tom Hazlett and John Wiley

For localized operations, mention was made of low-voltage induction equipment. Slides were shown to describe the actual application. Slides were also shown on luminous flame stress-relieving operations utilizing oil burners wherein the weldment being stress relieved acts as a firebox. These slides included various sizes and shapes of containers located both in the United States and foreign countries. Examples were a 40-ft sphere and coke digester 12-ft in diam by 100-ft high. Temperatures up to 1500° F have been used for such applications with inputs of 100,000,000 btu per hr. For heat retention and insulation from external cooling, rockwood is sprayed on the outside of the weldment being stress relieved.

A lively question-and-answer period following the presentation indicated the interest in the subject.

LARGE STRUCTURES

Sunnyvale—Members of the *Santa Clara Valley* Section enjoyed an informative discussion by Lynn Christensen of the Chicago Bridge and Iron Co. at the January dinner meeting held on the 24th at Sabella's Restaurant.

Of particular interest to the members and guests were the methods and practices that are being successfully used by construction people to stress relieve large structures at the actual location of installation.

Mr. Christensen's fine group of colored slides presented along with the discussion were of particular outstanding quality and very informative nature.

Process Fundamentals

San Jose—The Spring Lecture Series sponsored by the *Santa Clara Valley* Section took place on February 7th, 9th, 14th and 16th in the Engineering Building of San Jose State College, with an attendance of close to 100 at each lecture. The series covered the "Fundamentals of the Welding Processes."

The first night's lecture covered the subject of "Fundamentals of the Arc Welding Process (Metal Arc)." The lecturer, Edwin Olds, sales engineer for A. O. Smith Corp., Oakland, Calif., discussed: the metal-arc process and what it consists of, coated electrodes and what the coating does preparation necessary before welding, how fit-up affects strength of the welded structure, the difference between flat, vertical and overhead welding, hard-facing and its uses, how various

The one-third acre disk of this huge radio telescope, built by E. W. Bliss Co., turns on a 22 foot support bearing. Sperry ultrasonic testing was used to search the bearings' eight 4 inch plates for laminations and to thoroughly probe the vital welds.

Sperry Ultrasonics Tested the Key Welds

Whether it's this giant radio telescope, a gas transmission line or a vital pressure vessel, the nondestructive testing of key weldments has become standard procedure.

This is a major reason for Sperry's planned expansion in nondestructive test equipment. Both the new Sperry services are of the highest quality. Triplett & Barton X-ray offers light weight (the transformer head of the 300 KV model weighs less than 70 lbs.), continuous duty cycle, and high power (up to 300 KV with a full 10 milleamperes output). Sperry SONOFLUX® magnetic particle systems offer the exclusive features of infinite current control and fast, two second demagnetization.

Sperry is fully equipped to evaluate your weld inspection problem and advise the best solution.

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BIG BIG

The curtain's going up, April 18-20 in the New York Coliseum, on a brand new era of increased profits from the sale of acetylene gas. It's the **BIGGEST** profit-making advancement since Coyne Cylinder Company first introduced the Coyne "92" high-porosity filler. **NOW... FOR ANOTHER FIRST** Coyne brings you the industry's highest porosity filler in the industry's **BIGGEST** capacity acetylene cylinder.

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For details, circle No. 43 on Reader Information Card

power sources affect the welding job, and how the various welding currents and voltage settings affect the operator.

The large group of participants were very attentive throughout the $2^1/_2$-hr lecture period and expressed their thanks for a highly informative session.

The second night's lecture dealt with the "Oxyacetylene Process—Welding and Cutting." The fundamentals and basic information were discussed by Fred Stettner of the Victor Equipment Co., San Francisco. Major points discussed were: basic equipment, torches, regulators, gas supplies, oxygen and acetylene and other fuel gases; action of the inner and outer cones of flames; the fusion zone during welding; edge preparation and types of jobs are best done with gas welding.

The large group was very interested in the old stand-by method of gas welding which has been used for such a long time by the welding industry.

The third night's lecture covered "Fundamentals of the Tungsten Inert-gas Process." The speaker, Charles Robinson, manager of Process Engineering for Air Reduction Pacific Co., San Francisco, discussed the topic with the thought in mind that the listener was just starting in the welding industry, either as a new operator or for the first time as an engineer designing weldments requiring the use of the tungsten inert-gas process for fabrication.

The lecture covered power supply units, available inert gases, and the affect of each on the weld puddle and resulting weld deposit. The subject of weld joint preparation was thoroughly covered, and joint design was discussed in relation to the end results that were desired.

Mr. Robinson held his audience's attention throughout the evening, and the film he presented gave the listeners an idea of the importance of the tungsten inert-gas process in the welding industry both as a semiautomatic and automatic means to produce high-quality weldments.

The second speaker of the evening —Dr. Thomas Hazlett of the Mineral Research Laboratory of the University of California, Berkeley—discussed the "New Welding Processes" that are being used throughout the world as the welding industry advances in technical knowledge. Such subjects as electroslag, plasma-jet, ultrasonic, electron-beam, and friction welding were discussed in an informative and interesting manner. The question period was especially active with many questions being asked by the audience.

The fourth and last evening of the Spring Lecture series was planned to give the participants of the series a foundation and understanding in the "Fundamentals of the Metal-Arc Inert-Gas Process." The lecturer, Ron Skow, welding engineer in the Electrical Department of the Linde Co., San Francisco, gave a brief discussion on the history of the metal-arc inert-gas process and then thoroughly covered major fundamentals in a manner that gave the beginner a good basic background for future study and planned self-improvement. Such items as power-supply units, inert shielding gases, equipment components, joint geometry, joint preparation, usable materials and variations of the process were given full coverage. The question period following the lecture brought out many interesting facts.

At the close of the last lecture, Section Educational Committee Chairman Russell Rhoades with the assistance of Section Greeting Committee Chairman Don Ledwick presented the Santa Clara Valley Section certificate of award to those persons who had qualified by completing the course. Many of the persons who attended the lecture series expressed their thanks to the Section for the opportunity to attend such a well-planned and instructive lecture series.

Connecticut

HARD SURFACING

Bridgeport—Eldon Hurt of Haynes Stellite Co., New York, was the featured speaker at the January 18th dinner meeting of the *Bridgeport* Section held at the Fairway Restaurant. In his talk, "Mechanical Methods for Applying Hard-facing Materials," Mr. Hurt briefly reviewed the history of hard surfacing going back to 36 years ago. He also discussed the various uses of hard surfacing and the mechanized methods used today, in addition to showing slides of submerged-arc and tungsten-arc methods.

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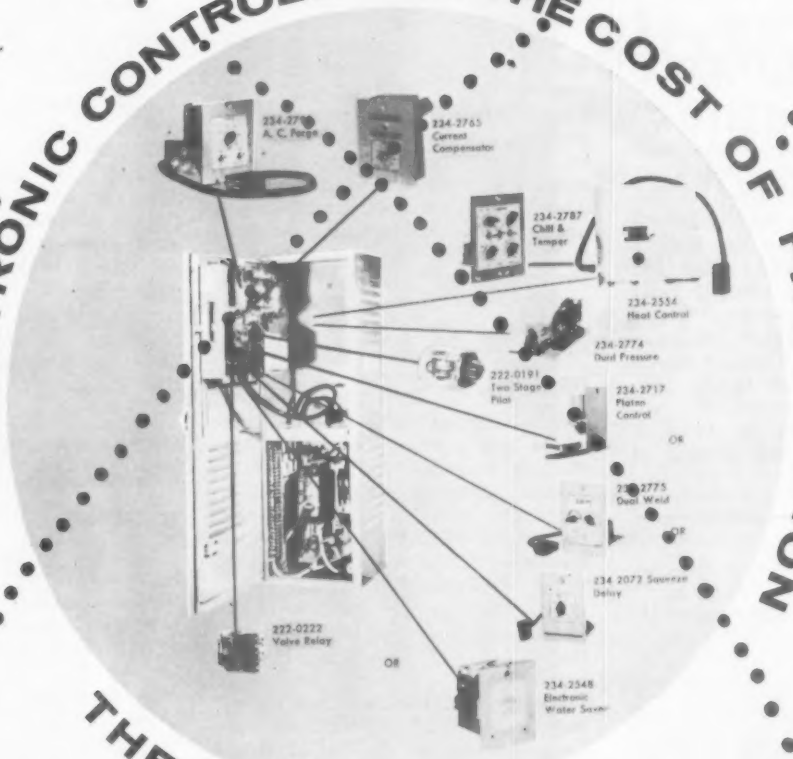

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District of Columbia

ATOMIC SUBMARINE

Washington—The *Washington* Section met for its final meeting of the calendar year on Thursday, Nov. 17, 1960, at the Washington Gas Light Auditorium. Dinner at the Hotel Ebbitt preceded the meeting.

The technical speaker was Nino Pompilio of the Electric Boat Div., General Dynamics Corp. Mr. Pompilio's talk dealt with the fabrication and welding of the world's largest undersea craft—the *USS Triton* built by the Electric Boat Div. of General Dynamics.

The hull of the Triton, made of steel purchased to Military Specification MIL-S-16113 Grade HT, is 100% welded construction. Approximately 400,000 lb of filler metal was used in the welding of the hull and the internals. Most of the hull was fabricated in the form of cylindrical sections—over 35 ft in diam—which were then butted together and welded. Use was made of automatic submerged-arc welding wherever possible.

Welding of the nuclear reactor system was accomplished by consumable-insert welding plus the manual gas-shielded metal-arc process. In the case of certain bimetallic joints required in the system, suitable techniques were developed. The performance of these joints under thermal and mechanical shock loading proved them capable of performing their intended functions, and the same techniques are being employed on all nuclear powered submarines.

BRAZING

Washington—The first meeting of the new year of the *Washington* Section was held on Thursday, January 12th at the Washington Gas Light Co. Auditorium. Dinner at the Hotel Ebbitt preceded the meeting.

The subject, "Current Advances in Brazing," was discussed by D. C. Herrschaft, assistant manager of the Brazing Products Div., Handy and Harman.

Demands of the missile and rocket industry for high temperature performance had led to the development of new brazing alloys and brazing techniques enumerated in the talk. The silver-copper alloys (silver solders) which find wide application for relatively low temperatures (up to 500° F) are not suited for higher temperatures (1000° F and up) operation required in missile and rocket components. Thus new alloys have been developed. These are the nickel-base, palladium-base, gold-base and manganese-nickel alloys. Some factors which must be considered in brazing are (1) alloys to be joined, (2) compatibility with brazing alloy with respect to erosion, formation of brittle compounds tending to reduce ductility, resistance to oxidation, (3) brazing atmosphere, (4) joint clearance, (5) brazing cycle and (6) pre-placing of brazing alloy.

Mr. Herrschaft explained how alloys such as Inconel 702, A-286, R-235, and 17-7 PH had been successfully brazed in a high vacuum when they could not be brazed in hydrogen atmospheres. It was pointed out that while the cost of many of the new alloys was extremely high, their use in missile and rockets can be easily justified since they are a small fraction of the cost of the finished item.

TWO SPEAKERS

Nino Pompilio, Electric Boat Div. of General Dynamics, as he spoke to the Washington Section on November 17th

Guest speaker D. C. Herrschaft (right) of Handy & Harman chats with J. Huminik of the Washington Section at the January 12th meeting

Florida

GAS-SHIELDED ARC WELDING

Hialeah—On January 18th, the *South Florida* Section held its fifth regular dinner meeting of the season at the Park Lane Cafeteria in Hialeah, where a delicious steak dinner was served.

Guest speaker for the evening was Wilbur H. McGrew, regional engineer for the Air Reduction Sales Co., Houston, Tex. Mr. McGrew's program was presented in a most gracious down-to-earth manner which held the members and guests interest throughout the lecture. At the conclusion of the program, Mr. McGrew answered many questions put forth to him by the audience.

Illinois

NATIONAL OFFICERS NIGHT

Chicago—The *Chicago* Section held its regular monthly meeting on January 20th at Peoples Gas Auditorium with an attendance of 110 members and guests. Dinner was held at Milner's Restaurant preceding the meeting. Because the Section was honored by the presence of President Thomas and Secretary Plummer, they called the meeting The National Officers Night.

Mr. Plummer gave a fine talk on the activities of the SOCIETY and its future plans. Mr. Thomas was the principal speaker and presented an excellent paper on electroslag welding. Mr. Thomas was instrumental in introducing this process to this country from Europe several years ago. Electroslag welding permits the welding of vertical joints in extremely heavy sections, a manner undreamed of a few years ago.

At this meeting Homer Gannett, who has been a member of the Chicago Section for the past 35 years, was given a certificate of appreciation from the SOCIETY and a plaque from the Chicago Section. In appreciation of what the SOCIETY has done for him, Mr. Gannett presented the SOCIETY with a $50 check for the building fund.

WELDING METALLURGY

Joliet—The *JAK* Section met on January 12th at Tony D'Amico's Restaurant for dinner and meeting.

D. C. Smith, chief metallurgist, Electrode Div., Harnischfeger Corp., gave an excellent and informative

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SIMPLIFY PIPE WELDING IN ADVERSE FIELD CONDITIONS

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TYPE CCC

Designed for quick easy alignment of pipe where the variation in inside diameters is relatively great. Chamfered NUBS allow close tolerance fit-up and CLEAN STRIKE OFF. The ROBVON NUB automatically sets root gap. ROBVON rings are beveled to assure non-restricted fluid flow.

TYPE CC

Designed to allow quick easy alignment of pipe where the inside diameters are slightly out of round. The welder has the choice of "STRIKING OFF" the NUBS or leaving them intact to be melted into the weld mass of the first roof pass.

TYPE C

Designed for precise close tolerance fit-up. Type "C" NUBS automatically sets root gap. The NUBS melt with the metal to give complete penetration and fusion.

PLAIN TYPE

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talk on "Recent Trends in Arc Welding Metallurgy." Mr. Smith captured the entire group with his easy-to-understand terms.

50 YEARS IN WELDING

Joliet—Feb. 10, 1961, was a very special meeting night for the *JAK* Section. Louie Perona (Mr. Welder) who has been in welding for 50 years (1911–61) was guest of honor. Bob Barnett, first vice chairman and Tony Gerl, advisory committee, did a take-off of "This is Your Life"—Louie Perona. Many of Mr. Perona's friends, whom he had helped to make welding history, were introduced. He was presented with a box containing some boiling wire which, as he recalled, was used for welding many years ago. He was also given a few stubs of a new iron-powdered rod representing the past and the present.

Main speaker of the evening was Jean Revelt of the Lincoln Electric Co., who gave a very fine talk on the Innershield process.

COVERED ELECTRODES

Peoria—The *Peoria* Section held its monthly dinner meeting at Vonachen's Junction on January 18th.

Guest speaker for the evening was H. F. Reid of the McKay Co., who spoke on the subject of "Coated Electrodes." In his talk, he reviewed the history of covered-electrode development and also discussed preheated welding wires.

Indiana

POWER SOURCES

East Chicago—The *Chicago* Section sponsored a Calumet Area Meeting on Jan. 12, 1961, at which Howard B. Cary of Hobart Brothers Co., Troy, Ohio, presented a talk on "Welding Power Sources." The talk covered the various types of power sources and applications. The numerous questions put to Mr. Cary indicated the tremendous interest of the audience in the subject.

One hundred and twenty-three people from the heavy industrial area of Hammond-Gary-Whiting, East Chicago, and the far South Side of Chicago attended the meeting. An excellent dinner of prime ribs of beef was served prior to the meeting which was held at the Jockey Club Restaurant in East Chicago, Ind. The committee which planned the affair consisted of Messrs. R. M. Kolb of American Oil Co., E. J. Zahumensky of Standard Railway Equipment and A. G. Craske of Calumet Welders Supply, Inc.

The desire of the Calumet Area welding people to attend meetings when held in nearby locations was demonstrated by the large turnout.

PLANT TOUR

Butler—The *Anthony Wayne* Section held its January 19th meeting at the Gerberhaus Motel in Fort Wayne.

After dinner, 35 members and guests drove to Butler, Ind., where they visited the Hendrickson Tandem Corp. After a brief talk on the history and operation of the plant by Vice-president Joe Parshall, the group toured the production plant including the truck shop where unusual and huge truck conversions and specialties are fabricated by welding.

The tour was arranged through the efforts of Winfred Keep.

SPIKE WELDING

Cumberland — Forty - seven members attended the January 27th meeting of the *Indiana* Section at Buckley's Restaurant in Cumberland. Following dinner and a short business meeting, Bob Lachner, sales manager of Robotron Corp., Detroit Mich., spoke on "Spike Power Welding."

Spike welding is a new power concept for resistance welding, utilizing pulses of short duration (1–2 msec) with extremely high current values delivered every half cycle of weld time. Spike power is accomplished with a bank of high-voltage capacitors and a new type of coaxial ignitrons in the welding transformer primary circuit. The capacitors impress a higher than normal voltage across the welding transformer primary and thereby produce a higher secondary welding current. Development of the spike power concept required design of new welding transformers. Transformer core size has been reduced with some increase in the copper conductor to handle the higher current. Several advantages were cited for spike welding: (1) smaller welding transformers are required; (2) welds can be made with lower forces, (3) secondary shunting is reduced, (4) the system appears to be self regulating since an increase in the secondary inductance effects an increase in primary voltage, and (5) welds exhibit a minimum heat-affected zone and less penetration and tend to approach a sold phase bond.

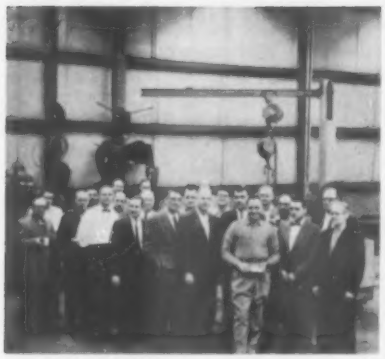
The shallow penetration generally results in shear failure through the nugget at higher test values than usually obtained with conventional resistance welds. The speaker pointed out that the usual concept of the ultimate strength associated with a pulled nugget does not necessarily apply to spike welds. A pulled nugget represents the strength of the heat-affected base metal and, since spike power minimizes the heat-affected zone, the actual shear strength of the spot weld is obtained. Slides of many

CHICAGO PRESENTATION AND SPEAKER

L. C. Monroe (left) and National President R. D. Thomas, Jr. (right) present certificates of appreciation at Chicago Section January 20th meeting to Homer Gannett for his 35 years in the SOCIETY. Mr. Gannett afterwards presented a $50 check to the SOCIETY for the UEC Building Fund

Howard B. Cary discusses "Welding Power Sources" at the Chicago Section meeting held in the Calumet Area on January 12th and attended by 123 members and guests from Hammond, Gary, Whiting, East Chicago and Chicago

PLANT TOUR



Some of the 35 members and guests of the Anthony Wayne Section who toured the Hendrickson Tandem Corp. after the January 19th meeting

specific spike welding applications were shown, illustrating a variety of material types and thicknesses. The utilization of spike power welding is still in its infancy, and the unusual application will benefit most by this new resistance welding concept.

METALLURGY

South Bend—The first two technical meetings of the season of the *Michiana* Section held on October 20th and November 17th, were attended by men engaged in all phases of the welding industry. W. G. Fassnacht, assistant chief metallurgist of the Bendix Corp., Bendix Products Div., South Bend, Mich., was the principal speaker on both evenings. His subject, "Basic Metallurgy for Welders," was presented in a series of two lectures and was very well received by personnel engaged in all phases of welding. This subject was the first of a series programmed by the Section for the 1960–61 year which will be devoted to the theme of a "Basic Welding Education Year."

The first lecture dealt primarily with the metallurgy of welding iron and steels. Mr. Fassnacht stressed the fact that welding and heat treating are very closely associated and that good welders must have a good working knowledge of heat treating as well as a sound background of welding fundamentals. This includes the fundamentals of metallurgy as applied to the rapid heat treatment that occurs during many welding operations. The functions of the iron carbon diagram and its intended use in predicting hardenability of the iron carbon alloys were thoroughly explained at a level all could understand.

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MEMORIES OF CHRISTMAS

A few of the many members and guests who attended the 1960 Iowa Section Christmas party. Left to right are: Mrs. and Mr. Max Weiss; Mrs. and Mr. Bill Koos; Alfred Smith and Mrs. Smith

The elements affecting weldability of the low alloy systems, as well as the austenitic and semiaustenitic systems were also covered.

The second session pertained to nonferrous alloy systems. Heat treatment accomplished by welding and its relation to the over-all welded joint was covered. Since the welding metallurgy of nonferrous alloys is quite different from ferrous alloys, this lecture was as equally well received as the first by all in attendance. The talks, illustrated with slides and blackboard, were followed by lengthy question-and-answer periods which closed the meetings.

The Michiana Section feels that, as welding technology increases in scope, more operators who are truly craftsmen to the extent of being self-dependent must be made available to industry in ever increasing numbers. The constructive teaching of welding fundamentals is not only very beneficial to the beginner, but it also helps refresh experienced personnel in all phases of welding. The lectures for the remainder of the year will be concerned with all phases of basic fundamentals.

POWER SOURCES

South Bend—The December meeting of the *Michiana* Section was held on the 16th at Russ Restaurant. "Power Sources for Welding" was the subject of a talk given by John F. Ruday of Armour Research Foundation.

The subject covered the variety of a-c and d-c electrical power sources available and utilized for welding. The advantages of several different power sources as applied to specific applications of the gas shielded-arc processes was discussed in detail. As a sidelight, it was pointed out how the need for improved welding processes had helped make available new and better power sources to meet the ever-increasing demand for improved welding quality control. The subject was discussed in a medium technical level.

ALLOY AND STAINLESS STEELS

South Bend—The plane was late and the reception committee was at the airport waiting patiently for it to arrive, when it was discovered that the speakers for the January 19th meeting were coming by train. After such an inauspicious start, the *Michiana* Section had a very wonderful National Officers Meeting, with both President R. D. Thomas, Jr., and Secretary F. L. Plummer present.

Mr. Plummer briefed the Section on the activities of headquarters during the past year, including progress on the new United Engineering Center and what is in store for the future.

Mr. Thomas discussed "Some Dramatic Applications of Stainless and Alloy Steel Welding." Certainly, anyone listening to that talk would get a new concept of the extensive field to which welding has been applied outside of the low-carbon nonalloy steel grades. From cracking stills to cryogenic containers, from airplanes to ships, such were the extremes covered. Of much interest was the description of welded submarine hulls.

Iowa

DISTORTION IN WELDING

Des Moines—LaMotte Grover, welding engineer with the Air Reduction Sales Co., New York, N. Y., was guest speaker at the January 19th meeting of the *Iowa* Section. Mr. Grover spoke on "The Control and Correction of Distortion in Steel Weldments."

Thirty-three members heard him discuss the results of unbalanced shrinking, procedures to keep heat controlled along the line of welding and how to provide adequate protection against the adverse effects of shrinking.

RESISTANCE WELDING

Des Moines—Arthur L. Williams, chief engineer of the Federal Machine and Welder Co., at a meeting of the *Iowa* Section held on February 16th explained the difference between various types and applications of resistance welding. In his talk on "Application of Resistance Welding," Mr. Williams described the operation and general construction of resistance welding equipment. The talk by Mr. Williams was well received.

Kansas

ELECTRON BEAM WELDING

Wichita—The *Wichita* Section of The AMERICAN WELDING SOCIETY held its February meeting on February 13th at the Shocker Room in the Student Activities Center of the University of Wichita.

Following an excellent roast beef dinner prepared by the student chefs, the 34 people in attendance enjoyed a semitechnical presentation on "Electron Beam Welding." William J. Farrell, chief application engineer with Sciaky Brothers, Inc., made the presentation. He fully described the process as well as its applications to industry and welding in particular. He used slides to assist his presentation, and welded samples of various metals were also shown to the group. It was a most interesting and educational meeting.

Louisiana

Flux-Cored Welding

Baton Rouge—The *Baton Rouge* Section met on January 19th for dinner and meeting at the Sherwood Forest Country Club. Speaker at the meeting was J. A. Howery of the Research and Development Dept. of National Cylin-

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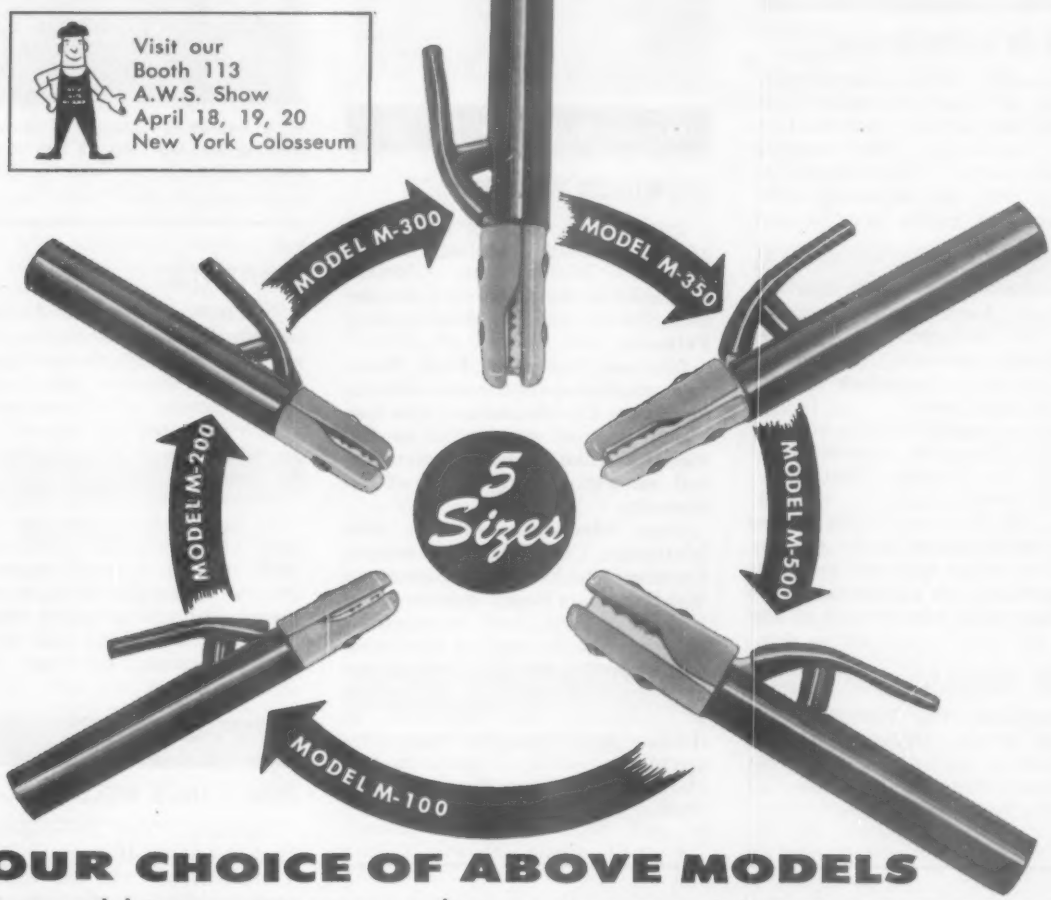

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Model No.	Amperage	Cable size	Electrode size	Weight
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M-200	200	1/0	5/32"	11 ounces
M-300	300	1/0 & 2/0	1/4"	19 ounces
M-350	350	1/0 & 2/0	5/16"	21 ounces
M-500	500	3/0 & 4/0	3/8"	27 ounces

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der Gas Co., Chicago, Ill. His talk was entitled, "Progress Report on the Fluxed Cored CO_2 Welding Process."

The presentation included a complete description of the process as well as equipment necessary for its use. This high-speed welding technique is rapidly becoming of greater interest in Louisiana.

Maryland

NUCLEAR SUBMARINES

Baltimore—The regular monthly meeting of the *Maryland* Section was delayed one week due to a severe snowstorm. The meeting was held at the James House on January 27th, and a crowd of 31 members and guests were present for dinner.

The after dinner speaker was a "revenooer" from the State of Maryland Alcoholic Enforcement Unit. Mr. Stewart, the speaker, gave a very interesting talk on the illegal whiskey operations in the State of Maryland.

Technical speaker for the evening was Nino Pompilio, welding engineer of the Electric Boat Div., General Dynamics Corp., Groton, Conn. Mr. Pompilio's talk on the plans and problems in the welding of nuclear submarines was very well presented and very informative for members and guests present at the meetirg.

POWER SUPPLIES

Baltimore—The February 17th meeting of the *Maryland* Section was held at the new home of the Engineers Club of Baltimore at at 11 W. Mt. Vernon Place.

Twenty-two members and guests enjoyed a delicious dinner in the club dining room. The after-dinner feature was the showing of a film on the vastness of outer space.

G. K. Willecke, research director for the Miller Electric Mfg. Co., was the speaker for the evening. Mr. Willecke spoke of the various power supplies for welding which are available and pointed out the reasons why each is necessary for a specific process. This talk was very enlightening and well received.

Massachusetts

ALUMINUM WELDING

Springfield—A very interesting and informative meeting of the *Western Massachusetts* Section was held in the Oaks Inn, Springfield, Mass., on Tuesday evening, February 14th.

National Secretary Fred Plummer, who had spent the day with the Executive Committee and who had visited two of the plants in the vicinity, gave a very interesting talk on forthcoming events of the SOCIETY.

Ivan MacArther of the Olin Mathieson Chemical Co. Research Division spoke on "Aluminum Welding — Past, Present and Future." That there is considerable interest in welding aluminum was evidenced by the questions put to him. The tungsten-arc welding of aluminum was explained in detail. A movie on the gas-shielded metal-arc welding of aluminum was shown and brought the evening to a close.

ALL THAT ONE CAN EAT

Dinner at the Old Mill in Westminster, Mass., was attended by 65 when the Worcester Section met on February 13th

DETROIT SPEAKER

W. G. Emaus as he spoke on resistance welding transformers at February 10th meeting of the Detroit Section

PLANT VISIT

Fitchburg—Herbert Jones was host to the *Worcester* Section during a visit to the Fitchburg Paper Co. plant on February 13th. An excellent turnout of 65 members and guests indicated the interest in the manufacture of one of the most common products in our lives.

It was most amazing to learn that only four men operate one of the large complex paper machines and that a great deal of emphasis is placed on the maintenance department which utilizes many welders.

Dinner at the Old Mill in Westminster preceded the tour.

Michigan

RESISTANCE WELDING

Detroit—"The Development of Package Type Resistance Welding Transformers" was the topic covered by William G. Emaus, Jr., manager of the Transformer Div., Kirkhof Manufacturing Corp., Grand Rapids, Mich., at the meeting of the *Detroit* Section held on Friday, February 10th, at the Engineering Society of Detroit.

Mr. Emaus traced the history of resistance welding transformers, showing their development from bulky units with long leads to the present day compact package type. This development was the result of requirements of the automotive industry and was made possible by the development and use of hypersil. The basic principles of transformer design, manufacture and usage, both old style and modern day, were discussed and illustrated with many slides.

These developments were correlated with tips on efficient usage of transformers in modern welding applications.

RESISTANCE WELDING

Grand Rapids—The *Western Michigan* Section met for its January meeting on the 23rd at Duck's Restaurant. The coffee talk was given by a representative of the local Post Office and a movie entitled "Goodbye Pony" interpreted the subject of "New Methods of Postal Handling." This proved an excellent coffee program.

Speaker for the evening was Joe Atkins, field engineer for the Bussman Co. of Toledo, Ohio. A very interesting and informative program on "Over Current Protection for Resistance Welding" was presented with the use of movies and slides as well as an actual demonstration of the protecting of overcurrent loads. Mr. Atkins provided the Section with one of the best top rate evening programs they have had the pleasure of sponsoring.

Minnesota

JOINT MEETING WITH ASM

Minneapolis—On Jan. 9, 1961, President R. D. Thomas, Jr., addressed a joint session of the *Northwest* Section and the American Society for Metals in an unusually interesting talk entitled "Some Dramatic Applications of Stainless and Low-alloy Steel Welding." Prior to his technical presentation, Mr. Thomas told the members of the

NATIONAL OFFICER GREETED

Two members of the Northwest Section greet National President R. D. Thomas, Jr., at the January 9th meeting. Left to right are: Section Chairmen N. C. Qualey, R. D. Thomas, Jr., and ASM Chairman J. A. McLaughlin

A MODERATOR AND PANELISTS

C. C. Anthes (left) of the Linde Co. and G. R. Spies (center) of the Air Reduction Sales Co. were panelists at the January 17th New Jersey Section meeting, with J. D. Wait (right) from Morrison Steel Co., as moderator

plans for the IIW meeting which is to run concurrently with the Spring Welding Show.

Earlier in the day, all committee chairmen and section officers were privileged to join Mr. Thomas at an informal discussion session of SOCIETY problems, held following lunch at Jax Cafe. All who attended this activity came away with a far better understanding of the aims and activities of the SOCIETY, plus a better appreciation of some of the problems involved in large stainless steel weldments.

New Jersey

OXY-FUEL GAS CUTTING

Newark—On January 17th, the *New Jersey* Section held a panel discussion on "Effective Use of Fuel Gases in Flame Cutting." The meeting took place at the Essex House in Newark.

G. R. Spies of Air Reduction Sales Co. and C. C. Anthes of Linde Co. were the speakers which J. D. Wait of Morrison Steel Co. was the moderator. Both talks were supplemented with very effective color slides.

The meeting and social "get-together" following it was attended by some 70 very interested members.

New Mexico

PLANT TOUR

Tijeras Canyon—The *Albuquerque* Section's February meeting was a plant tour of the Ideal Cement Co., in Tijeras Canyon, N. Mex., and was held on the evening of February 9th, at 7:30.

William Lockland conducted the tour, which was attended by 72 members and guests. Mr. Lockland did not start from the quarry due to the lack of sufficient lighting. However, he showed the group where the pellets about 1 in. in diam started through the crushers. This operation pulverizes the pellets into powder, collecting it and sending it through the kiln to dry. He also explained that the dust is collected in vacuum bags and reprocessed so that there is no loss. The plant can produce up to three million barrels of cement per year. If necessary it could be operated by one man.

Coffee and doughnuts were served after the tour.

New York

NUCLEAR FUEL ELEMENTS

Albany—Pete Patriarca, Oak Ridge National Laboratory, presented an excellent technical discussion on the "Welding and Brazing of Nuclear Fuel Elements" at a record attendance, despite the cold weather, of a meeting of the *Northern New York* Section held on February 2nd at Hot Shoppes in Albany.

During his talk, Mr. Patriarca emphasized the brazing techniques and various fixturing problems associated with the fabrication of fuel elements, both flat and tubular, for heterogeneous type reactors. An informative movie, describing the fabrication procedures used by ALCO Products in producing fuel elements for Oak Ridge experimental use, completed an evening of interest to the members and their guests.

SHORT-ARC WELDING

Olean—The *Olean-Bradford* Section held its monthly meeting on January 17th at the Castle Restaurant in Olean, N. Y. R. T. Telford of the Linde Co., Newark, N. J., spoke on short-arc welding with small diameter wires.

Mr. Telford's talk was accompanied with color slides and motion pictures of the short-arc technique. Everyone enjoyed the speaker and his subject very much.

WELDING METALLURGY

Rochester—The *Rochester* Section held its monthly meeting on Tuesday, January 17th at the Leiderkranz Club. The evening started with an Executive Committee

A SPEAKER WITH FRIENDS

P. Patriarca was guest speaker at the Northern New York Section meeting on February 2nd. Left to right are: L. E. Walker, W. A. Owczarski, P. Patriarca and C. H. Kreischer

meeting followed by dinner and a very good talk by Dr. G. E. Claussen of Arcrods Corp.

The talk and slides, "Metallurgy of Steel," were one of the best the Section has seen and heard on the subject. Dr. Claussen distributed printed outlines of his talk, which made it easier to follow and more interesting. Some of the points covered in the talk were "rimmed and killed steel," "melting and freezing of steel," "crystal structure" and "sulfur and hot cracking." "Hydrogen and porosity" also proved very interesting.

North Carolina

BASIC RESISTANCE WELDING

Raleigh—Thirty-two members and guests of the *Carolina* Section met for dinner and meeting in the Grill Room, cafeteria of the North Carolina State College, on the 23rd of January.

The speaker, Robert Foxall of the Federal Machine and Welder Co., Warren, Ohio, had as his subject, "Basic Resistance Welding—Machines and Controls." He first discussed the various devices that are used to provide the pressure needed, showing slides of the several types. He spoke of the need of specific pressures for the different metals. In a similar way he pointed out the definite need for the timing of the current according to a proved schedule of heating, particularly for the alloy steels and nonferrous metals and alloys.

Many users of spot welding machines have little knowledge of the reactance which greatly affects the useful current and is affected by the spacing between the arms of the machine. Mr. Foxall pointed out the necessity of measuring the actual weld current which is so often neglected, but which is very important in securing quality welds. Further, he spoke of the electrode pickup problem and of the need to follow the recommendations of the Resistance Welder Manufacturers Association as to the proper electrodes for the metals being joined.

NEW YORK FILLS UEC QUOTA

National Secretary F. L. Plummer (right) accepts check for $1460 from J. W. Flannery (left) and R. B. Thornton of the New York Section for the United Engineering Center

Ohio

WELDING POWER SOURCES

Columbus—On Friday, February 10th, a dinner meeting and technical session of the *Columbus* Section were held at the Florentine Restaurant. A "happy half hour of fellowship" preceded the dinner. G. K. Willecke, director of research for the Miller Electric Manufacturing Co., Inc., was the technical speaker. The title of his talk was "Welding Power Sources."

Mr. Willecke introduced his talk by giving a brief analysis of the arc welding process and emphasized that this is an integrated process involving many factors for a successful operation. Economic consideration, length of production runs, and similar factors governed the required equipment. Any lack of satisfactory results must first be examined from the standpoint of the complete process. He pointed out that most field applications not producing satisfactory results generally are due to misapplication of one or more of the integrated welding process factors.

The speaker then turned to the main problem of power sources. He showed the function of the power source and what its part is in the welding process. A discussion covering the basic differences between the a-c and d-c welding arcs and machines was given. The various static and dynamic characteristics, such as the volt-ampere curves, were given. He also talked about constant current, constant power and constant voltage characteristics. His concluding remarks covered the design and function of the rectifier type d-c power supply.

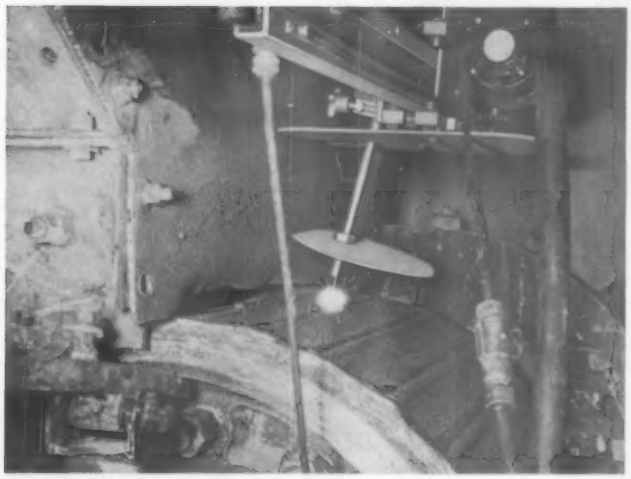
CONTROL FOR RESISTANCE WELDING

Dayton — The fifth meeting of the 1960–61 season of the *Dayton* Section was held at Kuntz's Cafe on Tuesday, February 14th. A friendly social hour preceded a fine dinner. An after-dinner feature was the showing through the courtesy of

DISCUSSES RESISTANCE WELDING

R. Foxall was guest speaker at the January 23rd Carolina Section meeting

Announcing 3 NEW STOODY Automatic Welding Systems!



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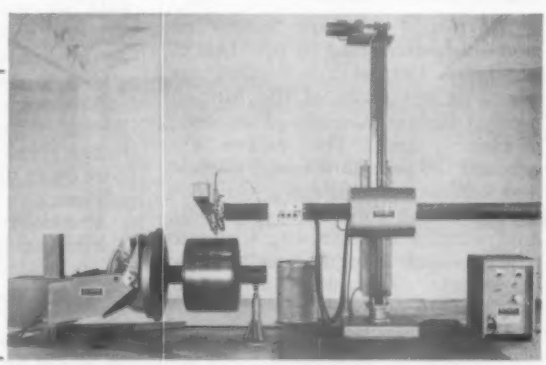

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A GUEST RELAXES

Guest speaker, P. L. Sommer (center) as he chatted with Tom Lorenzen (left) and Ben Schlatter at the January 18th Toledo Section meeting

Weiler Welding of a half-hour film on salesmanship.

Technical speaker for the evening was G. R. Archer of the Budd Co. As chief engineer of the Electronics Control Section, Mr. Archer spoke on the subject of feed back control for resistance spot welding. His talk was supplemented with slides showing basic mathematical equations relating various factors involved in the development of the control. The applications and limitations were discussed as were future areas of application.

PLANT TOUR

Marion — A very interesting and informative tour by members of the *North Central Ohio* Section was made of the plant of the Marion Power Shovel Co. on Thursday, February 2nd. The guides explained the procedures used to weld the various components. The tour included the forge shop, burning and cutting department, template storage and various welding departments. A highlight of the tour was the display of a brand new 20-x 20-ft manipulator with a-c, d-c tandem arc head.

Electronic tracing of the templates is used in the burning and cutting department. All of the templates are transferred to that department from the template storage via a monorail system.

Many large weldments for both mammoth shovels and draglines were being welded at the time of the tour. Judging from the many questions that were asked, it can be concluded that the tour was most successful.

POWER SOURCES

Canton—G. K. Willecke, chief physicist and director of research for the Miller Electric Co., Appleton, Wis., was the speaker at the January 19th meeting of *Stark Central* Section, and the reception that he received was excellent.

Speaking at the layman's level concerning welding power sources, Mr. Willecke kept interest high while, at the same time, advancing new concepts in power sources that brought many questions at the end of the discourse.

TIME STUDIES

Toledo — The *Toledo* Section held its monthly meeting at the Toledo Yacht Club on January 18th. Approximately 85 members and guests were honored by the presence of President R. D. Thomas, Jr., and Secretary Fred L. Plummer who, as coffee speakers, brought the members up to date on SOCIETY national affairs.

President Thomas complimented the Section for having pledged 100% of its goal toward the new United Engineering Center in New York. Secretary Plummer discussed the International Institute of Welding, of which he is a vice president and which will hold its annual meeting in the United States for the first time on April 11–19 in New York City.

Guest speaker was Phillip L. Sommer, standards supervisor of the LeTourneau-Westinghouse Co., whose subject was "Time Study for Welding" and created a great deal of interest. He explained in detail the procedure by which his company accumulated data on which standards are now based. Although a great deal of effort went into establishing a system, once established it is comparably easy to maintain.

PIPING

Toledo—Approximately 55 members and guests of the *Toledo* Section met at the Toledo Yacht Club on December 14th to hear Robert Wylie, manager of quality control for the Babcock Wilcox Co., discuss the fabrication of low-alloy and piping materials. The title of his talk was "Welding of Piping, Refinery Welding and Low Alloy Welding."

His talk was primarily limited to problems associated with material thicknesses of $^1/_2$ in. and greater. He pointed out the difficulty of locating defects in heavy sections by destructive and nondestructive tests. The quality control procedure is, therefore, designed to minimize defects during welding.

Oklahoma

DESIGN FOR WELDING

Tulsa—A joint meeting of the ASM, ASME and the *Tulsa* Section was held on Tuesday, February 7th at Stauffer's Recreation Center with a total attendance of 197.

Omer W. Blodgett, design consultant for The Lincoln Electric Co., Cleveland, Ohio, presented a very thorough discourse on "Designing for Welding." He covered the efficient use of welded steel in structural design and machinery design and manufacture. Discussed were ways to reduce material and labor costs, minimize detailing, improve appearance and function, and achieve new design concepts.

Pennsylvania

PANEL MEETING

Philadelphia—Despite the raging snow storm in Philadelphia on Friday night, February 3rd, all scheduled panel members as well as 14 AWS members and guests of the *Philadelphia* Section were on hand for discussion of nondestructive testing. All three panel members are to be commended on a very informative and interesting presentation which created so much discussion that it was necessary for Bill Brooks, panel chairman, to call attention to the fact the time was growing late and the meeting must be closed.

J. A. Rambo, Magnaflux Corp., discussed the application of magnetic particle and die penetrant as a tool for nondestructive testing. Kurt Schwartz, Universal Techni-

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cal and Testing Laboratories, Havertown, Pa., covered X-ray very well; and Byron Gates, Budd Co., discussed the pros and cons of the various nondestructive methods used and some of the considerations that must be given when choosing the best method for a particular job or result.

OXY-FUEL-GAS CUTTING

Shickshinny—The *Susquehanna Valley* Section met on February 1st at the Foothills Manor in Shickshinny. The topic of discussion was on "The Fundamentals of the Oxygen Cutting Process" and was delivered by Joseph F. Kiernan of the Air Reduction Sales Co.

Mr. Kiernan covered the oxygen-cutting process using three fuel gases, namely acetylene, propane and natural gas. He described the various types of cutting tip design and their uses. Each fuel gas when used with the prescribed tip has an optimum operating range for a specific thickness of material to be cut. The optimum for propane has a much more critical range than for acetylene and natural gas. An indicator for propane's best operating flame is a roaring noise accompanied by whistling.

The speaker stated that there has been much misleading information put forth by the proponents of the various fuel gases. There is no doubt that propane and natural gas can be more economical for many cutting operations. However, it is imperative that the individual user thoroughly evaluate his particular requirements and physical facilities before making any changes. Bevel cutting can be best done by the acetylene process. Therefore, this is one factor to be evaluated. Other factors are coordination of fuel gas requirements with general plant heating and alteration of fuel gas distribution systems—that is, will piping be of adequate size for the required added volume of low pressure natural gas?

Rhode Island

WELDING STAINLESS STEELS

Providence—The *Providence* Section held its monthly dinner meeting at Johnson's Hummocks on Wednesday, January 18th. The speaker, L. M. Petryck of the Inco Development and Research Div., gave an informative lecture on the welding of stainless steels.

Mr. Petryck discussed the selection of the proper grades of stainless steel for welding and the heat range required to minimize structural changes in the weld metal and heat-affected zones.

A plant tour to M & C Nuclear was discussed.

POSITIONING AND FIXTURING

Providence—The *Providence* Section held its monthly dinner meeting at Johnson's Hummocks on Wednesday, February 15th.

The Section had the privilege of hearing a talk by Willard Gunzelman of the World Electric Co. on "Saving Money Through Positioning and Fixturing." Mr. Gunzelman emphasized the high cost of depositing weld metal. For every welding dollar, 2¢ is spent on power, 4¢ on machines, 8¢ on electrodes and the balance of 86¢ goes to labor and overhead. It is obvious from this break down that the efforts for cost savings should be devoted to reducing the amount of labor that is needed to do the job, so stated the speaker.

He also pointed out that many welding shops today spend an excessive amount of time preparing the work for welding and that, through proper fixturing and the use of positioning equipment, this time can significantly be reduced. The use of this tooling will increase arc time, reduce handling time, and can cut the 86¢ worth of labor and overhead in half.

Mr. Gunzelman then showed a series of interesting slides illustrating a variety of positioning and fixturing machines. He also gave several case histories of how proper positioning reduced cost.

Tennessee

OUTER SPACE

Nashville—Fifty members and guests of the *Nashville* Section were present at the February 8th meeting held at the Dyer Observatory atop Observatory Hill.

Dr. Robert H. Hardie, associate professor of physics and astronomy and acting director of the Dyer Observatory, Vanderbilt University, presented a very interesting illustrated lecture on "A Guided Tour Through the Universe."

Prior to and after the meeting, the observatory was inspected and operational demonstration procedures were made. Dr. Hardie and his assistant answered at length the many questions raised by the members and guests.

ARC WELDING SCIENCE

Oak Ridge—The *Northeast Tennessee* Section held its regular dinner meeting on January 19th, at the Oak Terrace in Oak Ridge. The technical speaker was Clarence Jackson of the Development Laboratory, Linde Co., Newark, N. J. His subject, "Science of Arc Welding," covered the highlights of his

JOINT MEETING WITH ASM AND ASME

Some of the 197 AWS, ASM and ASME guests who heard Omer W. Blodgett of The Lincoln Electric Co. speak at the Tulsa Section meeting on February 7th

Reading left to right, the head table included Dale Davis (ASM), D. G. Ellis (AWS), G. A. Tomlinson (ASME), R. Kerwin (ASM), R. H. Wainright (AWS) and Dale Stauffer (ASME)

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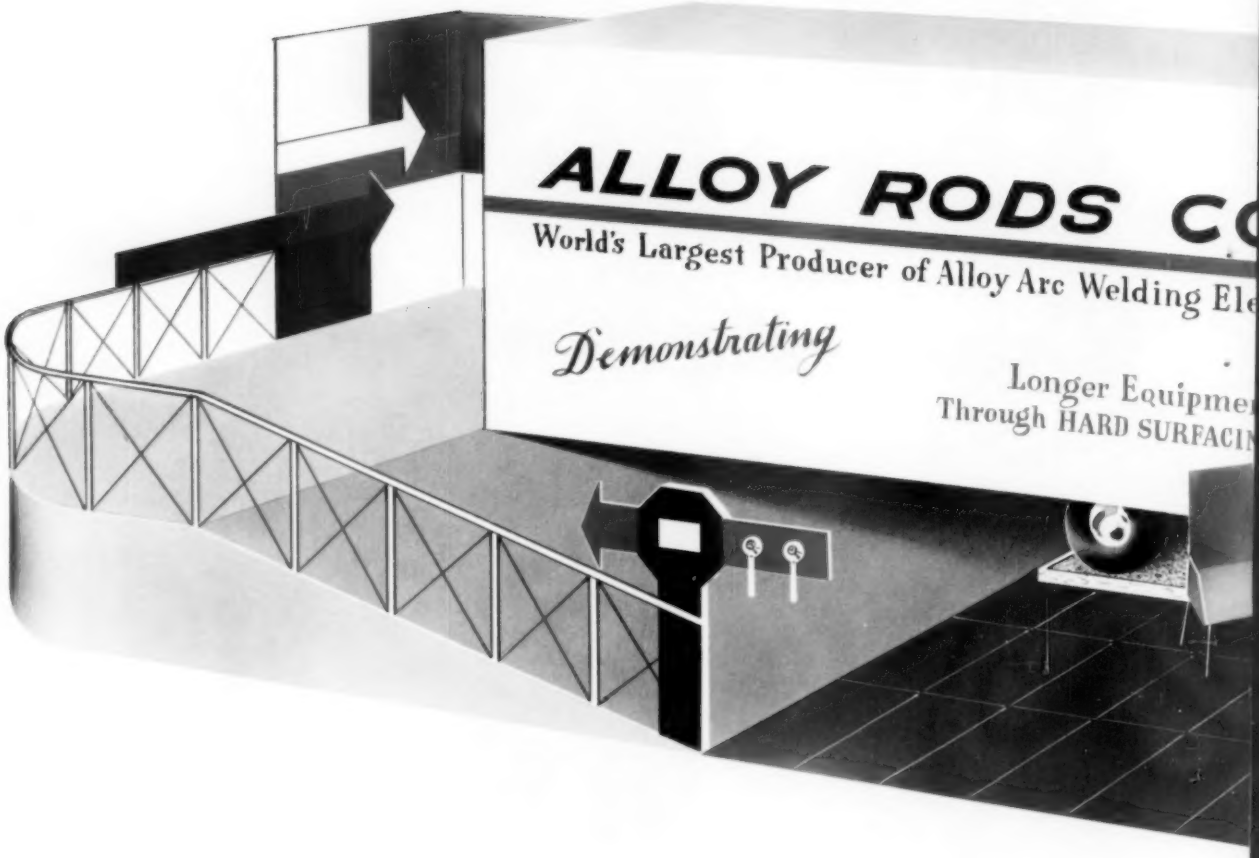

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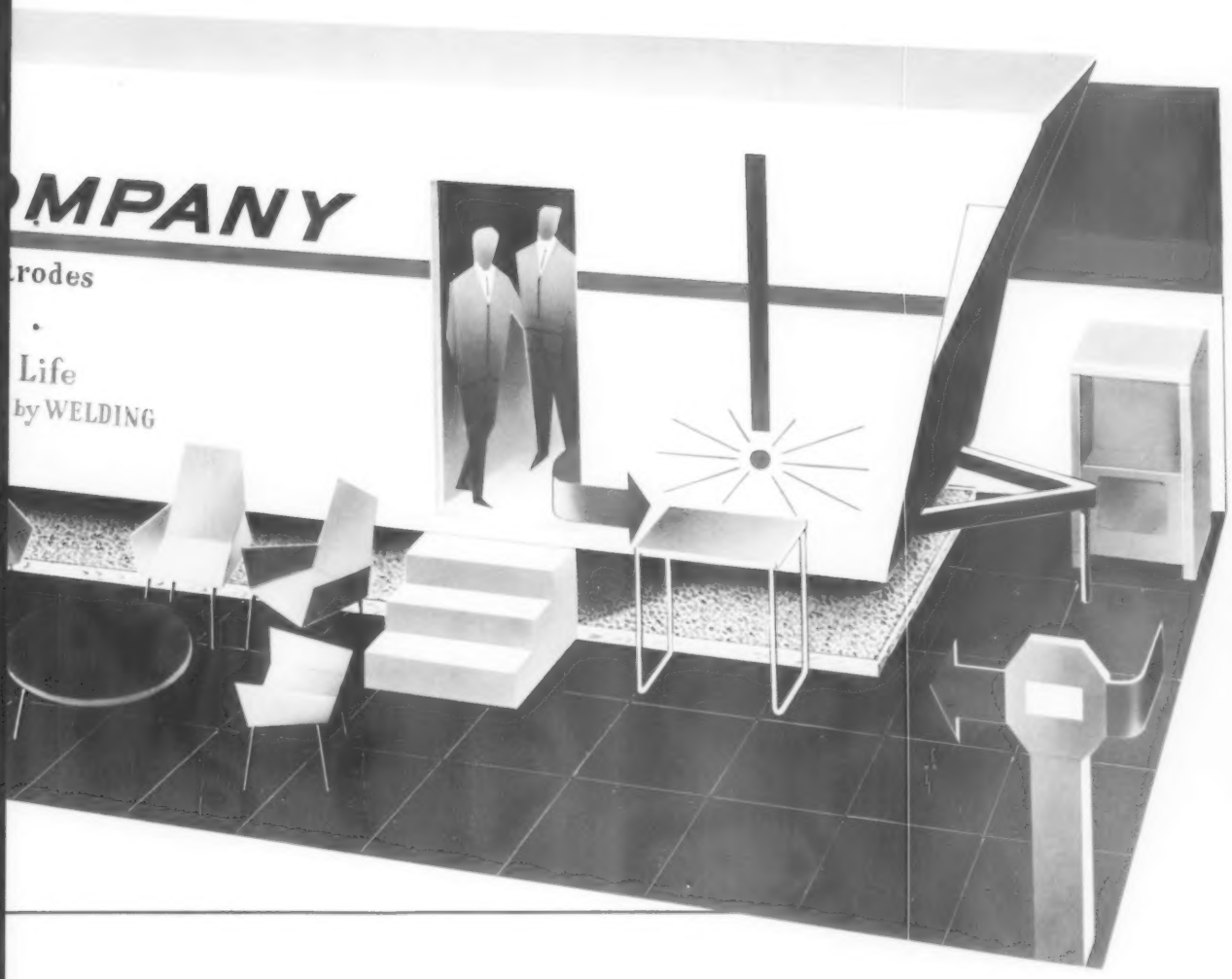

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A CHECK FOR NEW AWS HEADQUARTERS

Part of Holston Valley Section which met on January 17th when a check for the new Engineering Building was presented to National Secretary F. L. Plummer

Vice-president C. E. Jackson and National Secretary F. L. Plummer while with the Holston Valley Section on January 17th. Left to right are: C. W. Griffin, F. L. Plummer, J. Meyers, Jr. and C. E. Jackson

1959 Adams Lecture. The talk was supplemented by a number of very good descriptive slides.

Mr. Jackson outlined the history of arc welding and described various processes including several European developments that are rarely used in this country. He described friction welding in detail and showed slides of a deck welding unit that is used extensively in Europe to weld seams with a flux-covered reinforced type welding wire.

He concluded his talk by describing characteristics of the welding arc and showing how the science of arc welding can be applied to practical engineering problems.

MICROWIRE WELDING

Oak Ridge—The *Northeast Tennessee* Section held its regular dinner meeting on February 14th at the Dwarf Restaurant on the Oak Ridge-Knoxville highway. The speaker for the evening was John H. Headapohl, manager of sales and development at the Hobart Brothers Co., Troy, Ohio.

Mr. Headapohl gave a good account of the place that microwire welding occupies in the inert-gas consumable-electrode welding field. This process gives essentially the same arc characteristics as the "short arc" or "dip arc" processes. The wire diameters used are in the same range as those used in the other processes—namely, 0.020 to 0.035 in. The microwire welding process is used mainly for welding thin materials in the gage classes.

Examples of production applications were shown with color slides. Edge welding of gage compressor cases, welding of sheet metal transformer cases, the structural welding of a stair cat walk, and fabrication of a fertilizer spreader were a few of the interesting applications utilizing the microwire welding process.

One interesting sidelight of his talk was the operation of the stair cat walker with which the audience was completely unfamiliar. This is a new piece of handling equipment which has recently invaded the materials handling field, allowing one man to transport heavy refrigerators, freezers, washing machines up flights of stairs with ease. The heavy item is placed on the "cat." When the motor is activated, the "cat" crawls up the stairs with its pay load. The operator just guides the apparatus.

SCIENCE OF ARC WELDING

Bristol—Forty-three members and guests of the *Holston Valley* Section attended the January 17th dinner meeting held at Trayer's Restaurant Number Two at Bristol, Va. National Vice-president Clarence Jackson and National Secretary Fred L. Plummer were the guest speakers for the evening.

Mr. Plummer gave some timely remarks on the current activities of national headquarters. Mr. Jackson gave a very interesting presentation of "The Science of Arc Welding," a revision of his 1959 Adams Lecture. Mr. Jackson has contributed extensively to the science of welding. During his distinguished career, he has been associated with the National Bureau of Standards, U. S. Naval Research Laboratory and Union Carbide Corp. He is currently associate manager of Electric Welding Development at the Development Laboratory of the Linde Co., Newark, N. J.

BUFFET DINNER FOR A NATIONAL OFFICER

National Vice-president C. E. Jackson after he arrived at the Northeast Tennessee Section on January 19th. Left to right are: Jay Leonard, C. E. Jackson, Jim Clark and Pat Patterson

Buffet dinner attended by 30 members and guests before Mr. Jackson spoke on the "Science of Arc Welding"

One of the highlights of the evening was the presentation of a check from the Section to Mr. Plummer for the new engineering center.

Texas

ARC-AIR GOUGING

San Antonio—The *San Antonio* Section, met at Capt. Jim's on Monday, February 6th, with 44 members and guests present.

W. B. Hamilton, Jr., past section chairman and present program chairman, was presented with a plaque in recognition of his efforts and contributions to the success of the San Antonio Section. The plaque was unusual in that it was made of $^{3}/_{16}$ in. thick stainless steel and its face was rough-shot blasted. The AWS insignia and the writing was free-hand welded with manual arc method and made by members of the Section.

A. B. Vaught of Arcair was principle speaker for the evening. Mr. Vaught presented a series of slides showing the application of arc-air gouging. Originally the steel casting industry was one of the largest users of the process wherein the process is used to eliminate voids in castings. It has since become popular and a time-saver for multibeveling and gouging. A feature associated with the process is the weight advantage of weld metal deposit of U joints made with the process over U joints to obtain 100% weld subject to X-ray, thus saving joint preparation by means of beveling with the oxyacetylene process.

Mr. Vaught pointed out process uses in aluminum and stainless steel. It is also widely used in the maintenance field.

Wisconsin

SPOT WELDING

Appleton—"Spot Welding Processes" was the subject of a talk by A. C. Mulder, vice president in charge of production of Miller Electric Manufacturing Co., Inc., when the *Fox Valley* Section met at the Miller Plant No. 2 on Friday, January 27th.

Mr. Mulder gave a very effective blackboard talk, covering the processes used in spot welding, pointing out the fundamentals involved in each process and the more common errors made by operators when spot welding. The talk was well supported with specimens of good work with each process as well as the results of poor equipment operation. Mr. Mulder was assisted by his staff of laboratory assistants, who gave live demonstrations on the latest equipment available for resistance and gas-shielded-arc spot welding. One hundred and three members and guests were present.

VOCATIONAL PROGRAM

Appleton—In conjunction with a vocational guidance program sponsored by the *Fox Valley* Section, John Teigen, section chairman, addressed 80 students at the Appleton High School on the advantages of entering the welding field.

EDUCATIONAL PROGRAM

Milwaukee—During the month of January, the *Milwaukee* Section held its annual educational program, which was arranged by Educational program, which was arranged by Educational Director Robert Manning. The theme of this year's program was "Weldability of Ferrous Materials."

EDUCATIONAL ACTIVITIES

P. Ramsey, A. O. Smith Corp., talking on weldability of carbon and low-alloy steels at Milwaukee Section educational meeting on January 23rd. Other speakers were D. C. Smith, Harnischfeger Corp., on January 9th and A. L. Schaeffler, Allis-Chalmers, on January 16th

Milwaukee Section Chairman John S. McKeighan (right) with Mr. Wells (left) and Clint Busacca, Allis-Chalmers Co., welcoming educational program participants for plant tour on January 30th

Three lectures held at the Marquette University Science Building were well attended.

A PLANT TOUR AND VOCATIONAL GUIDANCE

A few of the 123 members and guests who attended the January 20th Fox Valley Section meeting and plant tour at the Miller Electric Manufacturing Co., Appleton, Wis.

Fox Valley Section Chairman John Teigen demonstrates point following recent vocational guidance talk on welding before 80 high school students in Appleton, Wis.

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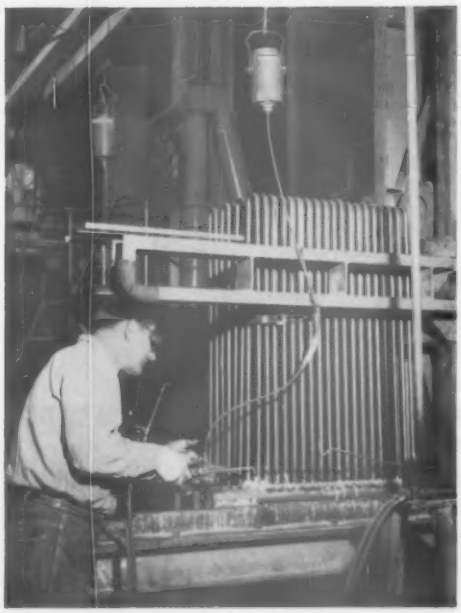

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CROSS-COUNTRY TRIP FOR NATIONAL OFFICERS

The Boston Section on February 13th was the first stop for National President R. D. Thomas, Jr., and National Secretary F. L. Plummer. Here left to right after an informal chat are: A. J. Rosenberg, Julius Ritter, R. D. Thomas, Jr., R. J. Lawless and W. V. Smith

Twenty-four hours later on February 14th National President R. D. Thomas, Jr., and National Secretary F. L. Plummer enjoyed themselves with the Western Massachusetts Section. Among those present were: left to right, L. W. Jaeger, Sr., I. A. MacArthur who was guest speaker, L. W. Jaeger, Jr., R. J. Trombley and H. B. Goodrich

The third stop was the Syracuse Section on February 15th. From left to right, greeting National President R. D. Thomas, Jr. (third from left) were: D. Tynew, M. Schaefer, Leo McAvoy, W. Brennan and W. L. Hughes

The fourth stop was the Madison-Beloit Section on February 16th where National President R. D. Thomas, Jr. spoke as shown here

Welcome

•Sustaining Members

Effective Jan. 1, 1961:

International Nickel Co., Inc.
New York, N. Y.

This company supplies electrolytic nickel for use in production of wrought or cast nickel-containing products including nickel-containing wrought and cast welding and brazing electrodes and wire. The company offers technical information and service on nickel-containing products and processes, including low-alloy steels, stainless steels, high-temperature alloys, nonferrous and nickel-base alloys, foundry products, welding products, plating, corrosion and catalysts. International Nickel also markets cobalt, iron powder, platinum and other precious metals.

Sustaining Member Representatives—T. N. Armstrong and W. F. Burchfield.

Huntington Alloy Products Division of International Nickel produces and distributes welding filler wire, coated electrodes and fluxes for joining of the more than fifty high-nickel alloys marketed under its trademarks Monel, Inconel and Incoloy. Additional products for the welding of cast iron and for joining dissimilar metals are trademarked Ni-Rod, Ni-Rod 55 and Inco Weld "A." Technical services on the products of the Division are provided through the Manager, Technical Service, Huntington 17, W. Va.

Sustaining Member Representative—W. C. Norton.

Effective Jan. 1, 1961:

Hamilton Electrona, Inc.
New York, N. Y.

Hamilton Electrona is the national distributor for Hamilton-Zeiss electronic beam welding equipment, which differs from conventional equipment in that it provides deeper penetration and narrower fusion zones through the use of high-voltage and very-high-energy concentration. The welding equipment is manufactured partly by Carl Zeiss in West Germany and partly by Hamilton standard Division of United Aircraft. Both firms are represented on the board of directors of Hamilton Electrona, Inc.

Sustaining Member Representative—I. Rossi.

Welcome

•Supporting Companies

Effective Feb. 1, 1961:

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Cambridge, Mass.

Effective Mar. 1, 1961:

Ford Motor Co.
Des Moines Implement Plant
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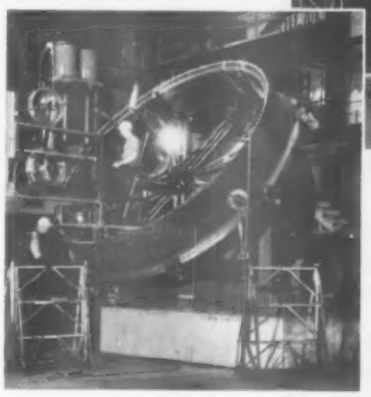

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EFFECTIVE FEBRUARY 1, 1961

MEMBERSHIP CLASSIFICATION

A—Sustaining Member
B—Member
C—Associate Member
D—Student Member
E—Honorary Member
F—Life Member

TOTAL NATIONAL MEMBERSHIP

Sustaining Members	202
Members	6,473
Associate Members	5,775
Students	339
Honorary Members	10
Life Members	31
Total	12,830

ALBUQUERQUE

Kuntz, George W. (C)

BOSTON

Borg, S. Edward (B)
Hagan, John T. (C)
Lovell, Charles P. (C)
Oldford, Robert (C)
Sampson, Warren P. (C)

BRIDGEPORT

Kregling, Gene W. (C)

CAROLINA

Arrington, James W. (B)
Bryan, David L. (B)

CHICAGO

Fannon, R. (A)
Gadus, Stephen A. (C)

CINCINNATI

Frame, Charles N. (C)

CLEVELAND

Andersen, Robert A. (C)
Flegge, James A. (B)
Forbes, Fred (B)
Frei, George E. (C)
Madsen, Orla (C)
McIntosh, John M., Jr. (C)

COLUMBUS

DeHaven, Cecil (C)
Molina, Carlos H. (D)

DETROIT

Bacalis, George J. (C)
Emery, Arthur C. (B)
Fetz, Alfred (B)
Kwasnick, Joseph (B)
Sowa, Zygmunt (B)
Sroka, Joseph J. (B)
Swartz, John Kenneth (B)
Weir, Marvin L. (C)

FOX VALLEY

Fess, William G. (C)
Hartman, Robert Allen (C)
Seaman, George W. (C)
Stoelting, Frederick A. (B)
Swant, James A. (B)
Walker, Earl C. (C)

HOLSTON VALLEY

Wood, Robert O., Jr. (B)

HOUSTON

Campbell, James F. (C)
Lee, Marvin L. (B)

INDIANA

Kirby, Richard B. (C)

IOWA-ILLINOIS

Cronau, W. J. (C)
Lamb, Robert S. (C)
McIntire, Charles (C)
Nelson, Edwin A. (B)
Taylor, Don R. (B)

J. A. K.

Moylan, James (C)

KANSAS CITY

Black, Robert H. (C)

LEHIGH VALLEY

Cologne, J. T., Jr. (B)

LONG BEACH

Taylor, James A. (B)

LONG ISLAND

McLaughlin, Albert R. (C)

LOS ANGELES

Samson, Frank C. (C)

MADISON-BELOIT

Luhman, George B., Jr. (B)

MAHONING VALLEY

Bianco, M. J. (C)
Mchar, Mike, Jr. (C)

MARYLAND

Barton, Raymond J. (C)

MILWAUKEE

Olsen, Dee L. (C)
Winter, William B. (C)

NEW HAMPSHIRE

Rivers, Edwin L. (C)

NEW JERSEY

Margerum, Benjamin R. (B)
Peck, James V. (B)
Pierowski, Walter (C)
Porter, Ben F. (D)

NEW YORK

Mandell, Sol H. (B)
Rossi, Irving (A)
Valento, Frank C. (B)

NORTH TEXAS

Bellinger, Thomas Peter (B)

NORTHERN NEW YORK

Besso, W. James (C)

NORTHWEST

Cope, James L. (B)
Root, Raymond F. (C)

NORTHWESTERN PA.

Olesa, Philip J. (C)

PEORIA

Gould, David S. (B)

PHILADELPHIA

Huber, Harry T. (C)
Kessler, Stanley (B)
Klevan, Mort (B)
Neilson, Donald J. (C)
Strable, Eugene C. (C)

PITTSBURGH

Hager, Frank L. (C)
Hahn, George F. (C)

PORTLAND

Averill, Dwight W. (B)

PUGET SOUND

Newcomb, John C. (D)

RICHMOND

Freed, Carl H. (C)
Kramer, Edwin C. (B)

SABINE

Hollingsworth, George S. (C)
Sadler, Donald L. (B)

ST. LOUIS

Archer, Basil (C)

SALT LAKE CITY

Behling, Jed (D)
Denton, Donald D. (D)
Israelsen, L. A. (D)
Mayfield, Donald L. (D)
Spackman, Darwin J. (D)
Wilkins, Vern (D)

SAN ANTONIO

Mauricio, Martin, Jr. (D)

SAN FRANCISCO

Drake, Vestal (B)
Forbyn, Norman T. (B)
Kulkowski, Stanley E. (B)

SANTA CLARA VALLEY

Britt, Eddie H. (C)
Shelton, Milo Garvis (C)

SYRACUSE

Cary, John E. (C)
Vogt, John N. (C)

TOLEDO

Fulton, D. Vance (C)

WESTERN MASSACHUSETTS

Schmidt, William A. (B)

WESTERN MICHIGAN

Stalec, John (B)
Whitaker, William B. (D)

MEMBERS NOT IN SECTIONS

Bernard, Andre (B)
Gross, Nicol Dr. (B)
Woolf, Jean Jacques (B)

Members Reclassified During February 1961

BOSTON

Brackett, David H. (C to B)
Quigley, Martin J., Jr. (C to B)

COLORADO

Scott, R. E. (C to B)

COLUMBUS

Dent, Paul (D to B)
Eichenberger, George D., Jr. (D to B)

DETROIT

Cruchet, Jules I. (C to A)

HARTFORD

McGlew, Henry A. (C to B)

HOUSTON

Grove, James R. (C to B)

KANSAS CITY

Ransome, D. C. (C to B)

NEW JERSEY

Cross, A. Stanley, Jr. (C to A)

NORTHERN NEW YORK

Marsh, Paul F. (C to B)

PHILADELPHIA

Pushkar, John J. (C to B)
Schaller, Philip H. (D to C)

PITTSBURGH

Nelson, Frederick G. (C to B)

SABINE

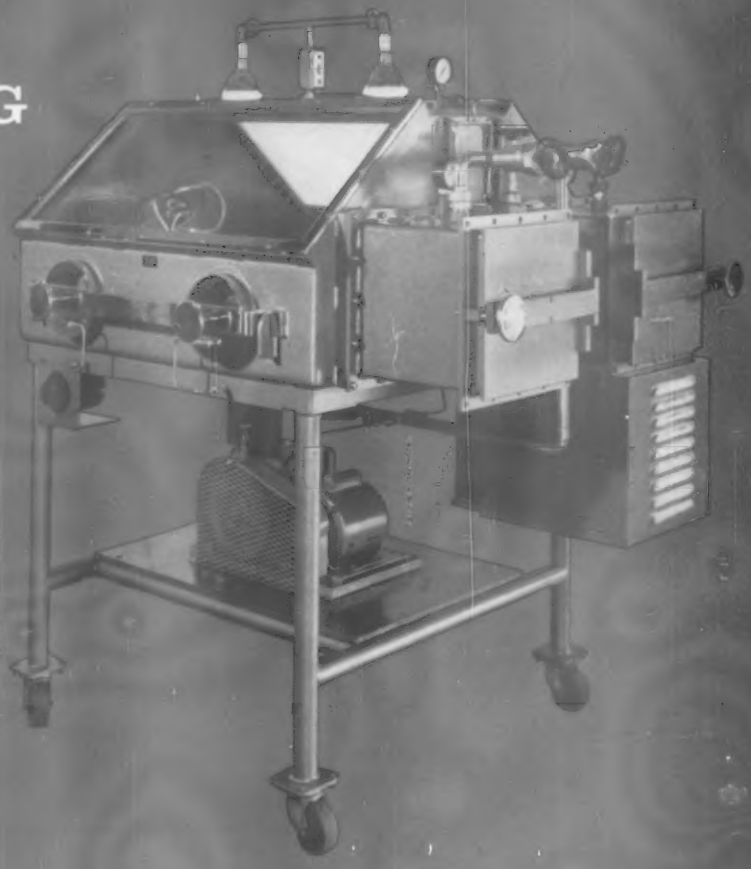
Buell, Sidney J. (C to B)

SAN FRANCISCO

Edises, Frank (C to B)

ROYAL RESEARCH CORPORATION

GAS WELDING ENCLOSURE



for
the containment of
selective inert atmosphere
in
welding rare metals

A growing need for precision control of inert atmosphere in welding of rare metals, such as molybdenum, tantalum, columbium or zirconium has resulted in this custom engineered enclosure. Outstanding features:

- HIGHER OPERATOR EFFICIENCY through increased window size.
- LARGER WORK SPACE AVAILABLE because of exteriorly mounted flood lights.
- MAXIMUM PURITY ATMOSPHERE resulting from low leak rate of less than one micron per minute at a base pressure of one micron.
- GREATER FLEXIBILITY through selective use of environments such as helium or argon.
- EASE OF ACCESS through four, eight-inch ERINSEAL glove ports permit two operators to work simultaneously.
- MAXIMUM ATMOSPHERE INTEGRITY because of gas-tight interchange vestibules.
- INCREASED RELIABILITY through heavy duty construction.

Inquiries regarding modifications or integration of this enclosure to fit your needs will be promptly handled.

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NEWS of the industry

McKay Acquires Automatic Welding Co.

The McKay Co. has acquired Automatic Welding Co., Waukesha, Wis., James C. McKay, president, announced recently. Automatic Welding Co. will be operated as a wholly-owned subsidiary of The McKay Co., whose headquarters are in Pittsburgh.

Automatic Welding Co. is a manufacturer of equipment used for all types of automatic welding, specializing in welding equipment for automatic hard surfacing. The firm was founded ten years ago by I. R. Bartter, president, and E. L. Matteson, vice president. Both of these men will remain in their present positions with Automatic Welding.

A. O. Smith Opens Western Sales Headquarters

The A. O. Smith Corp. recently opened a new Welding Products Div. district sales headquarters in Newark, Calif., home also of the West Coast office of the firm's Product Service Div. Manager of the new welding region is A. R. Schneller AWS, now responsible for sales out of the Division's western offices.

A. R. Schneller

An industry veteran, Schneller sold welding equipment for General Electric for several years before joining A. O. Smith in 1950. Since that time, he has managed both district and factory sales for the Welding Products Div., his latest post being Milwaukee, Wis., district manager.

British Exhibition Nears Opening

Arrangements are nearing completion for the Engineering, Marine, Welding and Nuclear Energy Exhibition which will open April 20th and continue to May 4th in London. More than 450 forums will be exhibiting, including approximately 40 who will be participating in just the welding portion of the exhibition

Among the exhibits is to be a twin-head fillet welding machine from Murex Welding Processes, Ltd. Arc Manufacturing Co., Ltd., will have a new 3-phase 45–400 amp TPR 400 welding rectifier suitable for all types of electrodes, particularly the low-hydrogen variety. AEI Transformer Div. will show a portable a-c atomic-hydrogen welding unit for use on light-gage sheet, chain links and hard surfacing; while A.R.D. Machine Co., Ltd., will display a new portable S.510 gun welding unit with built-in transformer and gyroscopic suspension for spot-welding light alloy sheet.

Additional terms include a 250-kva drum forming and welding machine to be exhibited by the British Federal Welder and Machine Co., Ltd., and an argon-arc spot-welding torch which will be shown by the British Oxygen Co., Ltd., together with a lightweight oxy-acetylene cutting blowpipe. British Industrial Gases, Ltd., will have a "Cutomation" oxy-propane profiling system and a multipurpose torch which can weld, cut, heat, flame clean, gouge and rivet wash, using low, medium or high-pressure acetylene, propane, butane or city gas.

Other welding exhibitors include Crompton Parkinson Ltd., English Electric Co., Ltd.; Fuller Electric Ltd.; Deloro Stellite Ltd.; Eutectic Welding Alloys Co., Ltd.; and Hancock & Co. Each will have an unusual display. For example, Eutectic Welding Alloys will feature a new process for welding cast iron in 1/10 th the normal time, while Hancock will have automatic electronic sensing for the "Hancoline" machine to keep burners at a given height above plate throughout profiling.

A special machine for the automatic welding of atomic reactor fuel elements will be featured by F. Hirschmann Ltd. On the other hand, a new "Sprite" CO_2 welding unit for semiautomatic hand welding of mild steel will be one of the items stressed by Lincoln Electric Ltd. Equally interesting displays will be sponsored by Hirst Electronic Ltd.; Interles Ltd.; New Process Welders Ltd.; C. S. Milne & Co., Ltd.; Oerliken Electrodes (G. B.) Ltd.; Portable Welders Ltd.; Donald Ross & Partners Ltd.; and Rockweld Ltd. To illustrate, Portable Welders will be showing a recently announced Fararc 300 welding rectifier to convert any a-c welder to dc.

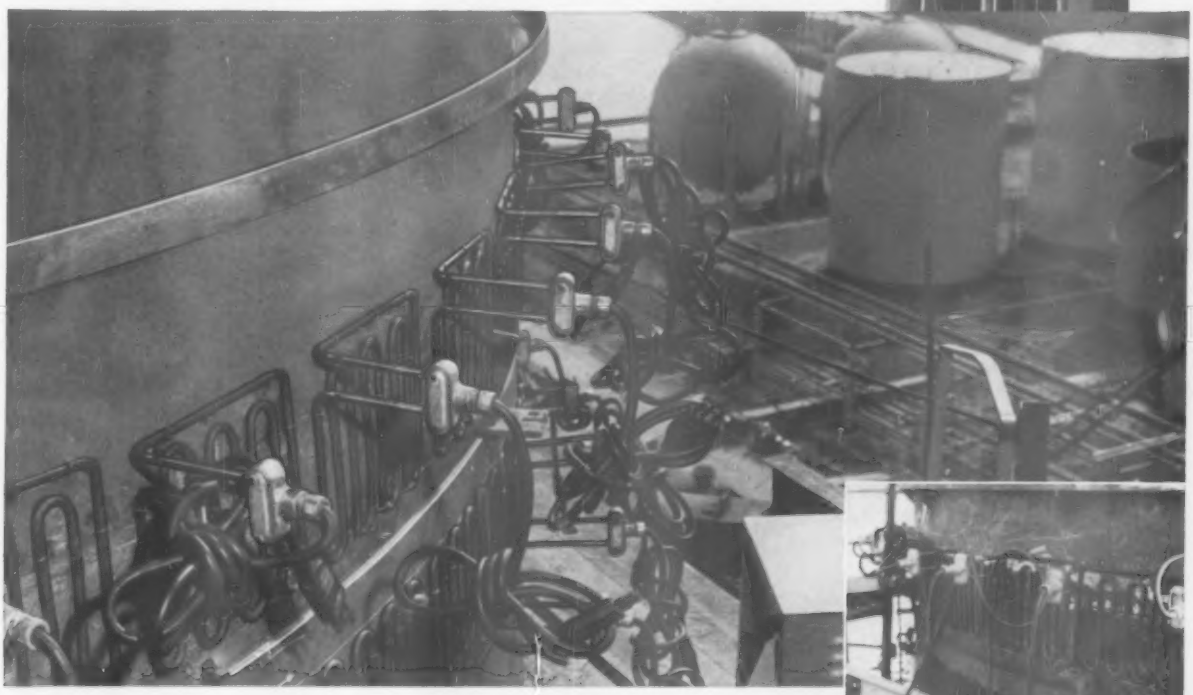
Nondestructive testing equipment will be featured by at least four organizations; Solus-Schall Ltd.; Watson & Sons (Electro-Medical) Ltd.; Ultrasonoscope Co. (London) Ltd.; and Research and Control Instruments Ltd. Indicating the versatility of testing equipment in display, Watson will have a new Xeroradiography process which produces high quality X-ray pictures 15 sec after exposure.

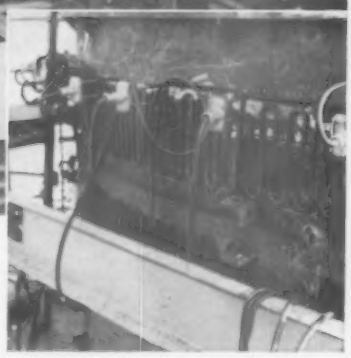
Weld a "cat" cracker 12 stories up . . . a nuclear power reactor . . . the hull of a missile-firing sub . . . or any hard-to-weld structure, of any size or shape, anywhere . . . with **economical, safe, versatile NOTTINGHAM Heatrol** systems for

Controlled, Concurrent

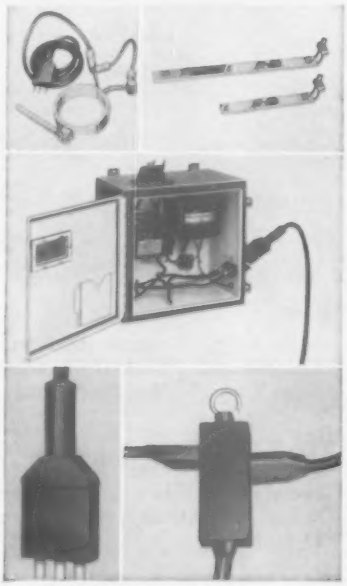
HEAT TREATING

Preheat • Postheat • Stress-relief annealing





CRITICAL PRESSURE-VESSEL WELDING, with one quickly installed system for preheat and stress-relief annealing, at temperatures up to 1,350° F, typifies the versatility of this new way to heat-treat with plug-in equipment. Electrical-resistance heater units (above and right) rapidly, uniformly heat any weldment, including piping — automatic controls (below) closely hold pre-set temperatures — molded Neoprene-insulated distribution systems grow with the job, provide COMPLETE SAFETY PROTECTION.



FULL-LENGTH HEATER ELEMENTS eliminate "cold spots," make intimate contact with weldments of various sizes and shapes, including pipe down to 3" diam (upper). **Pre-set any program** with automatic temperature-time controls (middle). **Plug-in power distribution equipment,** fully protected against electrical and physical hazards (lower).

PUTS YOU IN CONTROL OF WELD QUALITY. Automatically, continuously controlled heat-treating, concurrent with welding, permits strong, ductile welds on high-performance alloy steels. Waterproof reverse-taper connections assure dependable operation under all conditions.

SAVES TIME, CUTS COSTS . . . using, owning, maintaining. Even unskilled help can quickly connect and disconnect plug-in units, without cutting, splicing, taping, without tools . . . polarized plugs and receptacles prevent wrong connections. Use these rugged, interchangeable units on job after job.

COMPLETELY SAFE. Personnel and equipment are fully protected by built-in breakers and fuses, equipment-grounded circuits, molded Neoprene-insulated construction that prevents accidental contact. For complete technical information, ask

NOTTINGHAM *Heatrol*

Safety-engineered Building-Blok systems for controlled heat treating

J. B. NOTTINGHAM & Co., Inc. 441 LEXINGTON AVE., NEW YORK 17, N. Y.

For details, circle No. 25 on Reader Information Card

COMING EVENTS

A Calendar of Welding Activity

AWS

Apr. 17–21. 42nd Annual Meeting, Hotel Commodore, New York, N. Y.

Apr. 18–20. Welding Show, New York Coliseum.

IIW

Apr. 11–19. Annual Assembly. Sheraton-Atlantic Hotel, New York, N. Y.

AIME

Apr. 12–14. First International Symposium on Agglomeration. Sheraton Hotel, Philadelphia, Pa.

SESA

Apr. 17–21. Lecture course on Strain Gage Techniques. Granada Hotel, San Antonio, Tex.

WRC

Apr. 19. Annual University Research Conference, Hotel Commodore, New York, N. Y.

ASME

Apr. 23–25. Metals Engineering Conference. Penn Sheraton Hotel, Pittsburgh, Pa.

IAA

Apr. 24–25. Convention. Boston, Mass.

AFS

May 8–12. 1961 Castings Congress. San Francisco, Calif.

CWS

May 8–12. Canadian Welding Show, Toronto, Canada.

NWSA

May 8–10. Seventeenth Annual Convention, Hotel Commodore, New York, N. Y.

AIIE

May 11–13. 12th Annual National Conference and Convention. Sheraton-Cadillac Hotel, Detroit.

without the use of darkroom or wet chemicals.

Additional exhibitors include: Saturn Industrial Gases Ltd.; Electric Welding Machines Ltd.; Siemens-Schuckert (Great Britian) Ltd.; Smiths Industrial Div.; Suffolk Iron Foundry (1920) Ltd.; Vacu-Blast Ltd.; Weldcraft Ltd.; Kerry's (Ultrasonics) Ltd.; Distillers Co., Ltd.; Barker Machine Tools and Equipment Ltd.; Rowen-Arc Div. of Ruberg, Owen & Co. Ltd.; F. Bode & Son Ltd.; Holden & Hunt Ltd.; Pollock & Peel Ltd.; and Yates Plant Ltd.

Honorary president of the exhibition is to be A. I. Baker, chairman of the Baker Perkins Group of Companies.

Record Sales for Airco

Sales of Air Reduction Co., Inc. for 1960, established a new record of $202,486,344, it was announced recently by John A. Hill, president. Sales in 1959 were $200,603,636.

Net income in 1960 was $14,692,381 as compared with 1959 net income of $14,850,600. Earnings for the year 1960 were $3.73 as compared with 1959 earnings of $3.81.

In the fourth quarter of 1960, sales were $49,354,634 and net income was $3,078,133. In 1959, fourth quarter sales were $49,550,743 and net income was $3,405,898. Earnings in the fourth quarter of 1960 were $0.78, as compared with fourth quarter 1959 earnings of $0.87.

Metal & Thermit Opens Detinning Plant

Metal & Thermit Corp. recently opened a new half-million-dollar detinning plant in Tampa, Fla., the first detinning facility in that state, it was announced by H. E. Martin, president.

The new plant, located on an 11-acre site, will serve industry in Florida and neighboring states. "This area's rapid industrial growth in the past few years has created a need for a local processor of high-quality tin plate scrap that results from can-making operations," Mr. Martin said.

The Tampa facility is the latest step in M & T's planned expansion program and is one of three new plants scheduled for the Detinning Div. As recently announced, a similar plant will be opened this year in Hamilton, Ont.

The new installation will use a modern chemical process to recover tin from tin plate scrap. Because the United States is almost entirely dependent upon imports of tin to fill its requirements, reclamation of this basic metal through detinning operations serves an important function for industry.

MIDWEST WELDING CONFERENCE

Among the 300 persons attending the seventh annual Midwest Welding Conference February 1st and 2nd, at Armour Research Foundation, Chicago, Ill., were (standing, left to right) O. T. Barnett, Armour Research Foundation; A. F. Chouinard, National Cylinder Gas Co., and president-elect of the AMERICAN WELDING SOCIETY; F. J. Winsor, Foster Wheeler; H. E. Adkins, Kaiser Aluminum Chemical Sales and H. Schwartzbart, supervisor of welding research, Armour Research Foundation.
Seated from left to right are: E. D. Baugh, Westinghouse Electric Co.; C. Jackson, Linde Co.; and W. H. Wooding, Arcos Corp.
A total of 12 technical papers were delivered at the two-day conference on all phases of welding. The conference is sponsored annually by Armour Research Foundation and the Chicago Section of the American Welding Society

SCIAKY...
FIRST IN ELECTRON BEAM WELDING

Advanced Sciaky Design Combines Research and Production Capabilities into One Machine

If *you're* interested in electron beam welding, here's why you should investigate Sciaky machines:

SCIAKY ELECTRON GUN DESIGN...

Simple, rugged and compact! Exceptional electron optics produce beam density previously possible *only* with accelerating potentials as high as 100,000 v. The Sciaky gun, entirely contained within the atmosphere of the welding chamber, will operate in any angular position. *Both* gun and fixture can be moved to any position within the chamber while welding. Advanced focusing design results in welds with 12 to 1 depth to width characteristics.

SCIAKY PUMPING SYSTEM...

Fast and efficient! Depending on chamber, only 3 to 10 minutes are needed to evacuate chamber to welding pressure. Pumping sequence is *completely* automatic with built-in safety devices.

SCIAKY SAFETY...

Unmatched! Low voltage (30,000 v. maximum) and highly refined chamber design eliminates x-ray hazards, which are a severe problem with higher voltage equipment. No costly shielding is needed.

Call or write for details of these and other Sciaky machine features. Regardless of your specific area of interest, you'll find Sciaky's combination of extensive welding experience and advanced electron beam technology to be helpful.

Sciaky is Exclusive Licensee under the Stohr U. S. Patent 2,932,720 80C6102

You can learn more about Sciaky Electron Beam Welding, fully automatic TIG and MIG Welding with modular or building block concept, and the newest in Bench Welding at the

A.W.S. Welding Show, New York Coliseum, April 18, 19, 20,
Booth 729

SCIAKY BROS., INC., 4919 WEST 67th STREET, CHICAGO 38, ILLINOIS • PORTSMOUTH 7-5600

For details, circle No. 26 on Reader Information Card

TUFFALOY FORGINGS

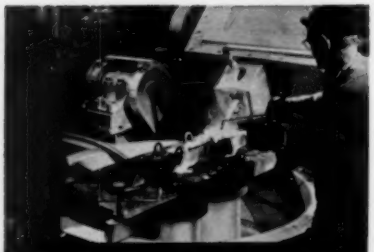
Fault-Free and Right on Spec

TUFFALOY forged seam welder wheels provide the utmost in conductivity and long life. Photo by Taylor-Winfield Corporation.

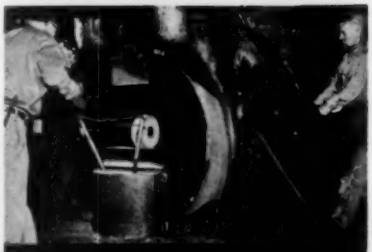
To carry the current they should and withstand the pressure they must, resistance welding alloy parts have to be right on specification both as to composition and structure.

RWMA specification forgings by TUFFALOY are used for seam welder wheels and shafts, butt and flash welder dies, and welding platens. TUFFALOY'S more than twenty-five years in producing these forgings have led to the establishment of the largest stock of forged bars and wheels anywhere.

For fault-free forgings—wheels (finished or unfinished), square or rectangular bars, and special shapes of all kinds, all heat-treated or cold-worked to maximum hardness, specify TUFFALOY.



TUFFALOY alloys are semi-continuously cast into twenty-foot long billets for greater uniformity of structure.



Forging the desired shapes from heated segments of TUFFALOY billet under a steam hammer takes rare old-world skill.

Doc Tuffy says . . . *to make sure every TUFFALOY forging meets hardness requirements, every forging is tested individually. TUFFALOY people will always go a step further to maintain product superiority.*

Write or call your nearest AIRCO or TUFFALOY distributor. Ask whether your forging needs are now in stock. Ask him too for the TUFFALOY catalog . . . it makes correct alloy and tip specifications easy.

THE TRADEMARKS TO TRUST

AIRCO

AIR REDUCTION SALES COMPANY

A division of Air Reduction Company, Incorporated

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More than 700 Authorized Airco Distributors Coast to Coast

On the west coast: Air Reduction Pacific Company. Internationally: Airco Company International. In Canada: Air Reduction Canada Limited

ALL ARE DIVISIONS OR SUBSIDIARIES OF AIR REDUCTION COMPANY, INC.

See us at Booth 320 in N. Y., April 18–20.

For details, circle No. 45 on Reader Information Card

New Welding Process

A new welding process that is said to hold a promise for greater efficiency in spot, seam and projection welding has been developed by research metallurgists at Armour Research Foundation.

It is termed fiber-metal resistance welding, and its basic concept involves fiber metallurgy, an ARF development in which thin fibers of metal are interlocked like a felt cloth.

Fiber metal resistance welding uses a piece of fiber-metal sheet between surfaces that are to be resistance welded.

According to Harry Schwartzbart, AWS, ARF assistant director of metals research, the fiber-metal sheet greatly increases the ratio of the contact resistance to the bulk resistance, allowing the metal in the fiber mat to reach its melting point faster, while the base metal remains relatively cold.

He said the advantages of this new process are:

1. Greater efficiency, and lower power requirements than in conventional resistance welding.
2. The possibility of making resistance welds of high conductivity metals like copper.
3. Ability to weld cold-worked or heat-treated metals without destroying weld properties through recrystallization. This is important in resistance welding of refractory metals like tungsten and molybdenum.
4. In projection welding, it allows more relaxed dimensional control and fit-up, greater reproducibility, and ability to weld larger areas and parts.
5. Less electrode indentation in spot and seam welding.

Foreign Patents

Aeroprojects Inc., West Chester, Pa., was recently granted a British patent on ultrasonic welding equipment and methods, and a British and a Canadian patent on a support mount for such vibratory devices.

Sciaky Research Division Transferred

Sciaky Bros., Inc., has transferred its Research Division formerly located in Los Angeles, Calif., to their recently enlarged plant facility at 4915 W. 67th St., Chicago, Ill. This move was made to centralize and integrate Research and Development work with the main plant's laboratory and manufacturing activities, according to Sciaky.

Messer Representative

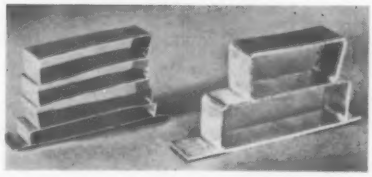
Messer Cutting Machines, Inc., has appointed the Edward A. Lynch Machinery Co., Inc., of Wynnewood, Pa., as its exclusive representative for the sale of the Messer line of flame cutting machines in the following areas: Eastern Pennsylvania, Southern New Jersey, Delaware and Maryland.

Wheelabrator Forms Canadian Company

Formation of a new Canadian company—Wheelabrator Corp. of Canada, Ltd.—was recently announced by James F. Connaughton, chairman of the board. The new corporation is the successor to the Canadian Division of Wheelabrator Corp., Mishawaka, Ind., and was organized to handle expanding sales and fabricating activities for all provinces in Canada.

New Process for Joining Copper Parts

A significant development in the copper industry was revealed recently by Chase Brass & Copper Co., a subsidiary of Kennecott Copper Corp.



Edge-to-surface diffusion-bonded copper assemblies consisting of 0.005-in. thick strip at left and 0.025-in. thick strip at right

According to Glenn P. Bakken, president of Chase, the company's Research & Development Dept. has devised a new technique for joining copper to copper and certain alloys to copper. Cost savings, easier production methods and improved products are said to be among the advantages which may result from the new technique.

In the Chase process two or more copper components can be joined together with a homogeneous bond which is said to be as strong as or stronger than the base metal. A special coating on the metal surface diffuses into the parts to be joined and under proper conditions produces a bond without an interface. It is stated that joints made in this manner retain virtually all of the high electrical and thermal conductivity of copper. This reportedly will be especially advantageous for many electrical and electronic applications.

Tests on diffusion bonded joints have shown them to be markedly superior to soft soldered joints in respect to tensile, shear and properties, according to Chase. Corrosion resistance in many media is also expected to be appreciably higher.

Spike power Welding

Visitors to the Institute of Radio Engineers show at the Coliseum in New York City, March 20th–23rd, saw the first public demonstration of transistor manufacture by spike-power welding. A special working exhibit, set up by the Lansdale Div. of Philco Corp., demonstrated the new resistance welding method in assembling transistors for use in rockets, missiles, computers and other precise quality applications where reliability requirements exceed those of run-of-the-mill radio and television transistors.

The spike power method is reported to be ideally suited to transistor manufacture—particularly where high quality is indicated—because its inherent minimum heat generation eliminates the danger of damage and distortion to sensitive parts.

FOR REBUILDING YOUR WORN CRAWLER UNDER-CARRIAGE PARTS, AND DIVERSIFIED WELDMENTS **Automatically**

A ROYAL SERVICE CAN BE YOURS

Revolutionary engineering design eliminates the unnecessary... Built-in versatility secures your present and future rebuilding needs . . . Minimum day-to-day operating costs . . . Thorough operator training at no additional cost... One source of supply for you—manual and/or automatic!

A ROYAL WELCOME AWAITS YOUR REQUESTS

Rexarc INCORPORATED West Alexandria, Ohio. U. S. A.

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The single-station automatic welder which was used in the Philco exhibit was built by National Electric Welding Machines Co., Bay City, Mich., which has previously supplied Philco with Spike Power transistor welders for its Lansdale, Pa., facility. National Electric also supplied the capacitors for the unit. The specialized welding control for the I.R.E. show unit was furnished by Robotron Corp., Detroit, Mich.

Lincoln Announces Price Reductions

The Lincoln Electric Co., Cleveland 17, Ohio, has announced a general price reduction for welding machines, electrodes and supplies. Individual reductions range up to 12.5%. This action, says company president William Irrgang, is taken at this time to help users of arc-welding equipment meet the challenge of competition and rising costs.

According to Lincoln, the price change reflects a long established policy of setting prices according to its manufacturing costs and reducing those prices as costs are reduced. Today's prices of welding equipment are lower than they were 25 years ago in spite of a rise in the cost of raw material and labor during the same period to a point where these are now more than three times what they were in 1936.

Quantity Pricing Procedure

The Babcock & Wilcox Co. Tubular Products Div. recently announced a new pricing procedure within the welding fittings industry. The company stated that its new policy, which became effective Jan. 21, 1961, will enable distributors to provide better service to purchasers of welding fittings and flanges. The new pricing procedure reportedly will make it economically possible for distributors to maintain adequate stocks, thus providing improved service to users. It was pointed out that the new procedure does not call for any increase in prices.

Under the new pricing procedure, distributors should be able to carry a complete stock and thus provide the ultimate user shortened delivery time. In addition, it can reduce the distributor's cost of "planned" stock replacement and can provide an increase in sales for out-of-stock transactions.

M & T Foreign Subsidiary

Metal & Thermit Corp. has formed a wholly owned subsidiary in Zug, Switzerland, to increase its participation in the growing European market, it was announced by H. E. Martin, president. The new subsidiary, Metal & Thermit AG, will act as the parent company's sales and licensing representative in Europe. It will also license its own patents and trademarks.

Dr. Hartmut Richter will be associated with the Swiss subsidiary as Technical Director. He was formerly European Technical Representative for M&T. Metal & Thermit AG, will be a part of M&T's International Division, headed by Charles H. Carpenter, Jr.

Pacific Northwest Metals Conference

In connection with the Century 21 Exposition there will be a Pacific Northwest Metals Conference at the Benjamin Franklin Hotel, Seattle, June 7–9, 1962. Sponsoring local societies include the American Society for Metals, the AMERICAN WELDING SOCIETY and the Society for Nondestructive Testing. A series of technical sessions will be presented covering corrosion problems, metals for high-temperature service, nuclear reactor metallurgy, metal fabrication and melting and casting. A group of distinguished speakers will be announced at a later date.

The Pacific Northwest Metals Conference will be under the direction of a working committee headed by Chairman Ernest R. Telford, Materials and Processes Engineer, Boeing Airplane Co. Dr. Earl C. Roberts, Professor, Mineral Engineering, University of Washington will be program chairman.

Syntron Appoints Representative

The Semiconductor Div., Syntron Co., Homer City, Pa., has named Hilltronics, Inc., Detroit, Mich., as sales representative for the lower Michigan Peninsula.

Hilltronics, Inc., will represent the division in the sale of its selenium rectifier cells and stacks, selenium cartridge rectifiers, silicon diodes and stacks, and newly-developed semiconductor devices as

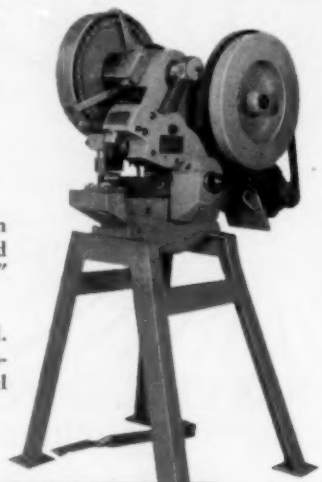
Large and Small Fabricators of steel and ornamental iron swear by it ...

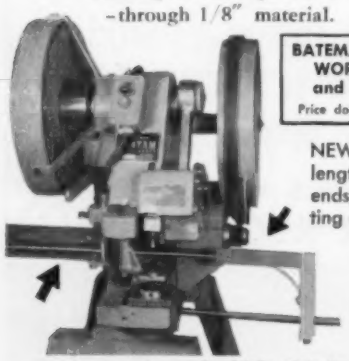
BATEMAN BANTAM IRON WORKER

The Bantam cuts and punches fast and clean . . . no grinding necessary. It's versatile, and saves time and labor! Cuts 2" x 2" x 1/4" angle and 1/4" x 4" flats.

Punches 1/2" hole through 1/4" material. Operates by hand or foot, uses 3/4 hp motor (1750) rpm., powered with flywheel and drive gear.

The Coper will cope 1-1/4" –through 1/8" material.





BATEMAN BANTAM IRON WORKER, with motor and stand $575.00
Price does not include Blades, Punches or dies.

Shp. Wt. 750 lbs.

NEW ACCESSORIES: Gauge for cutting to length, Guide for Flat Bars for cutting on ends, and Angle Iron Trimming Guide, for cutting at a 45 degree. Write for details.

WRITE TODAY for complete information and name of nearest distributor

Bateman Foundry & Machine
MINERAL WELLS, TEXAS

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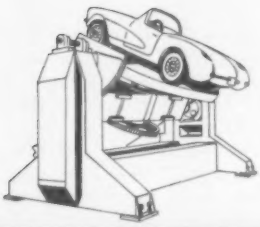
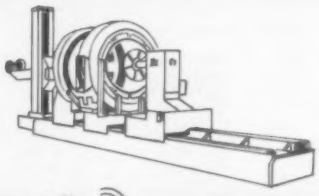
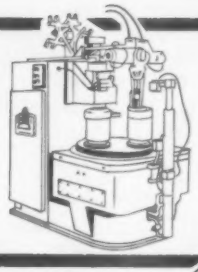


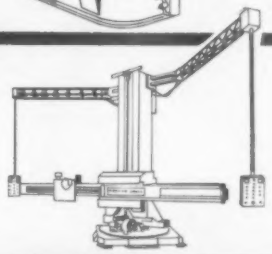
POSITIONERS



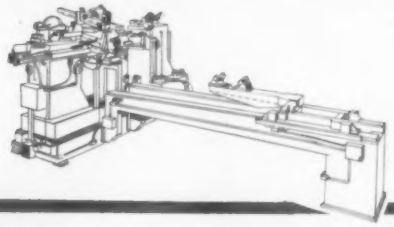
WELDLATHES



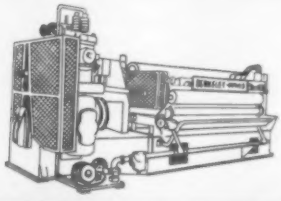
DIAL FEEDS



MANIPULATORS



TRANSFER MACHINES



SPECIALS

Better Welding Is Our Business

BERKELEY-DAVIS, INC.

DANVILLE, ILL.

Subsidiary of The McKay Machine Co., Youngstown, Ohio.

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they are released. Territory to be covered by Hilltronics, Inc., will be the lower Michigan Peninsula with the exception of Berrien, Cass and Van Buren counties.

New Furnace Processing Plant Opens

A new furnace processing plant has been opened in San Antonio, Tex., by Stainless Processing Div. of the Wall Colmonoy Corp. R. L. Peaslee [illegible], vice president and general manager of the division, who made the announcement, said that the move has been made to meet expanding demands for brazing, bright annealing and furnace heat treating service in the Southwest.

The new plant houses high production pit-type furnace facilities which will handle parts up to 28-in. diam by 35-in. high. The equipment is instrument-controlled and used with pure, dry hydrogen atmosphere and other standard protective furnace atmospheres. Stainless Processing Div. has other brazing and processing facilities in Detroit, Morrisville (Pa.), Montebello (Calif.) and Dayton (div.)

Named manager of the new plant is L. E. McIlvain, who brings to his job 35 years of experience in the metals and metal processing field. Prior to joining the Stainless Processing Div., McIlvain had been chief metallurgist at Kelly Air Force Base for 7½ years.

Airco Welding School Broadens Technical Service

Technical service to customers is being broadened by the Air Reduction Sales Company's electrode welding school for field organization personnel. Located at its electrode and wire manufacturing plant in Sparrows Point, Md., the course is essentially a training program for Airco salesmen and technical representatives, covering electrode operating characteristics and procedures for determining the type and size electrode to best meet the requirements of various applications. Competitive as well as Airco manufactured electrodes are studied. These include mild, low alloy and stainless steel, iron powder, low-hydrogen and hard-surfacing electrodes.

The course—initiated by H. O. Westendarp, product sales manager, Airco electrodes—is run on a twice-a-month basis with each course lasting a week.

The training expands and improves the technical service of Airco personnel, enabling them to help customers select the right material for a particular application. It also gives the men a firm technical background to help them cope with many special applications which arise in the field.

Trucks for Lease to Welding Industry

A new, low-cost plan, under which special-body trucks used in the welding industry can be leased without maintenance for from four to eight years, was announced re-

NEW RODS

NEW LOW PRICES

NEW "TUFF-TOP"

MOLY-NICKEL Hard Facing Fuse-Well No. 16 Rods

- NICKEL-COPPER Fast-Flow Fuse-Well No. 66 Rods
- No. 22 Dual Purpose Cast Iron Electrodes

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Weld Rod Division
CHICAGO HARDWARE FOUNDRY CO.
North Chicago, Illinois

FUSE WELL

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BOUND VOLUMES . . .

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now available at $20 per volume

Black cloth binding with
gold lettering

Volumes for previous years
also available in
limited quantity

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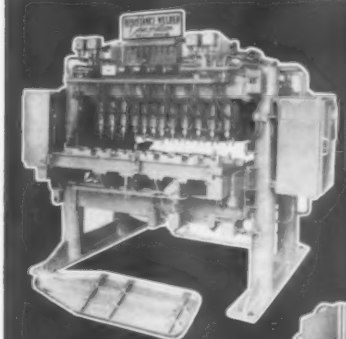
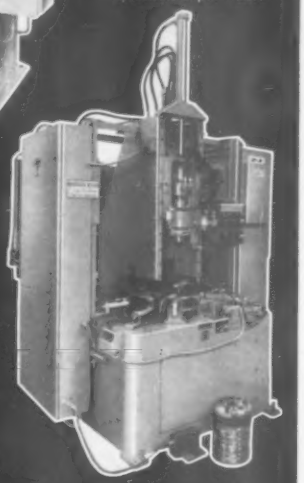
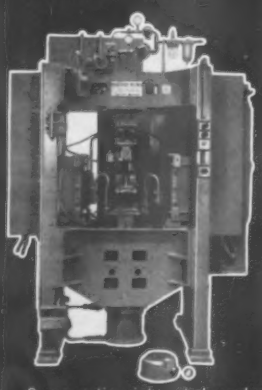
33 West 39th Street
New York 18, N. Y.



Shuttle type three (3) station multi-spot welder makes total of (60) spot welds on ironing board . . . 240 assemblies per hour.

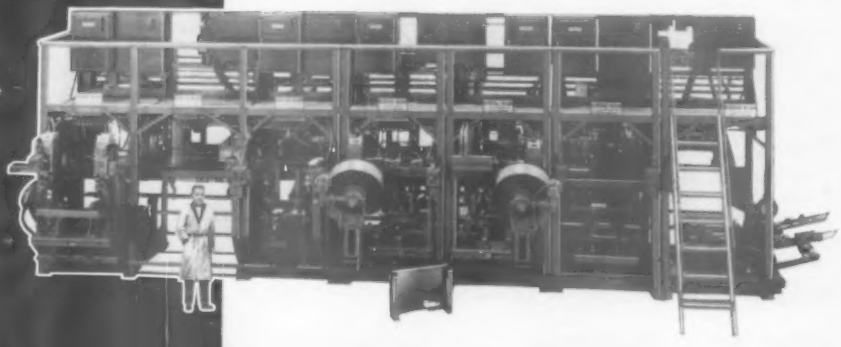


Stack, Stretch and Tack welding machine assemblies Inconel Rings of varying diameters and widths to produce close tolerance Aircraft Engine Outer Combustion Chambers; (16) tack welds per joint, (9) joints per assembly . . . production 20 complete assemblies per hour.



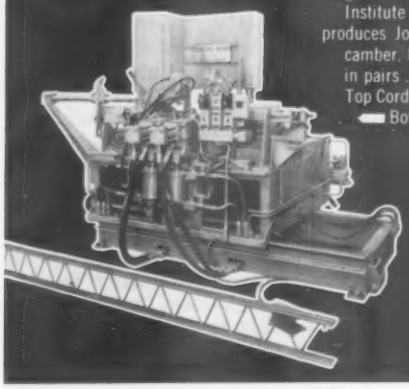
Four post, multi-transformer machine for highest quality welding of large ring projections. Unit shown is tooled for welding Fusite Terminal to Refrigerator Compressor Housing with auxiliary tooling for welding Terminal Guard.

Seven station, integrated, production line with hoppers and magazines feeding rails, slide channels, weld nuts and brackets which are welded to panel to make complete refrigerator Deck weldments . . . adjustments for 24" to 36" wide Deck . . . 48 spot and projection welds per weldment . . . production 450 per hour.



MEMBER RESISTANCE WELDER MANUFACTURERS' ASSOCIATION RWMA

Machine produces Joist assemblies, is adjustable for gauging and welding various sizes to Steel Joist Institute requirements and produces Joists with required camber. Machines are used in pairs . . . one unit welds Top Cord to Web; one welds Bottom Cord to Web.



greater EFFICIENCY

Do these examples of high production resistance welding and multi-purpose machines suggest a solution to a bottleneck in your production? . . . a cost reduction on your welded assemblies? High production welding and allied equipments designed for a minimum of manual handling.

- higher production • lower unit costs
- save floor space and handling costs
- uniform quality

- complete line of standard spot, projection, seam and flash-butt welders
- special welding and multi-purpose machines
- complete automated production lines

RESISTANCE WELDER *Corporation*

TWINBROOK 2-1506
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cently by Wheels, Inc., 6200 North Western Ave., Chicago 45, Ill. The company said the long-term lease plan was an innovation for special-body, over-the-road equipment used by welding firms. This equipment can reportedly now be leased without full maintenance, repair and garage service.

According to the company, there is no limit to the type of special bodies and chassis which can be leased under the special-body truck lease plan. In order to qualify for a special-body truck lease, however, a firm must meet the following conditions: (1) the company must have a net worth of $1 million, and (2) the company must have a record of profitable operations.

Hughes Appoints Representatives

The Vacuum Tube Products Div., Hughes Aircraft Co., Culver City, Calif., has appointed two new sales representatives for its line of precision electronic welders.

Brooks, Feeger & Associates will represent the line in Arizona, Utah, Eastern Idaho, Montana, Wyoming, Colorado, New Mexico and El Paso County, Tex. Their main office is located at 5510 Domingo Rd., N. E., Albuquerque, N. M., with branch offices in Englewood, Colo.; Scottsdale, Ariz.; and Salt Lake City, Utah.

Instruments for Measurements, 3455 Cahuenga Blvd., Hollywood, with a branch office in San Diego, Calif., has been appointed for the Southern California area.

Radio-Telescope Contract

The General Dynamics Corp., Electric Boat Div., Groton, Conn., was recently awarded a $19,314,432 contract to provide the drives and controls for the Navy's 600-ft "Big Dish" radio-telescope.

Prime contractors for the entire $100,000,000 telescope project, now under construction at the Naval Radio Research Station, Sugar Grove, W. Va., are Tidewater-Kiewit-P.E.C.

In addition to the drives which will support and rotate the 30,000-ton telescope, Electric Boat Div. will also supply the electronic control systems to interpret signals from the telescope's computer so as to position the world's largest moveable land object with the accuracy of a fine watch. The electronic ears of the telescope's $7^1/_2$-acre "Big Dish" are expected to have an interstellar range of billions of light years.

When the telescope is completed, part of the total operating time will be given to purely scientific studies such as radio astronomy, research in the characteristics of the earth's atmosphere and gathering new geodetic and geomagnetic data on the earth itself. The remainder of the time it will be used for advanced research in radio communications and navigation.

Electric Boat's subcontract calls for providing 128 azimuth drive units to support the entire telescope structure and 128 elevation drive units to support the two semicircular altitude "ferris wheels" on which the Dish is mounted. The design of these units will permit each of the 256 drive rollers to have roll, pitch, yaw and translation motions to prevent stress on the telescope structure from temperature changes, winds and icing conditions. A hydraulic equalization system will insure that all rollers in a quadrant will share the weight equally. The azimuth drives will rotate the entire telescope structure about a vertical axis while the altitude drives will rotate the Dish about a horizontal axis to elevate or depress the reflector from horizon to zenith.

Wins Safety Award

Lukenweld Div. of Lukens Steel Co., Coatesville, Pa., now called the weld department of the firm's Fabricating Division, has been presented the top award in the 1960 safety contest sponsored jointly by the Steel Plate Fabricators Association and the National Safety Council.

Lukenweld earned the high safety honor with a disabling injury rate in 1960 of only 1.87 for every million man-hours worked during the year, compared to a 14.06 average for competing association members. Lukenweld earned second place awards in 1958 and 1959.

Stupp Weldment Department

Completion of a new 40,000-sq ft weldment department addition to Stupp Bros. Bridge & Iron Co. facilities was announced recently by Erwin P. Stupp, president.

The addition will provide better, more exact, more complete service on weldment specifications of any size, he said. Now in operation, it makes possible increased production of a large variety of expertly fabricated weldments and welded structures, Stupp explained.

Some equipment includes: fully-automatic manipulators, capable of welding speeds up to 105 ipm; semiautomatic welders; motor-driven, manually-guided welders; shielded-arc welders capable of precision welding on aluminum, stainless steel and other metals and alloys; welding positioners with 360-deg rotation and 135-deg tilt, and capacities up to 32,000 lb; a Duograph simultaneous multiple-pattern cutting machine.

The overhead handling equipment, Stupp added, includes numerous hoists and cranes. Capacities are to 50 tons, with some having a clearance of 35 ft.

WELDING ENGINEERING COURSE

Participants in first biennial short course on welding engineering which was conducted Dec. 5–8, 1960, at the University of Illinois by the Departments of Civil Engineering, Mechanical Engineering and Industrial Engineering, and Mining and Metallurgical Engineering in cooperation with AWS

Allis-Chalmers Awarded Contract For Plasma Jet Test Stand

North America Aviation, Inc., recently awarded a contract to Allis-Chalmers for the design and construction of a 1-mw plasma jet test stand facility. The facility will be located at North American's Los Angeles Division plant in El Segundo, Calif. As prime contractor, Allis-Chalmers assumed complete responsibility for the plasma generator, expansion nozzles, test section, power supply, control and instrumentation.

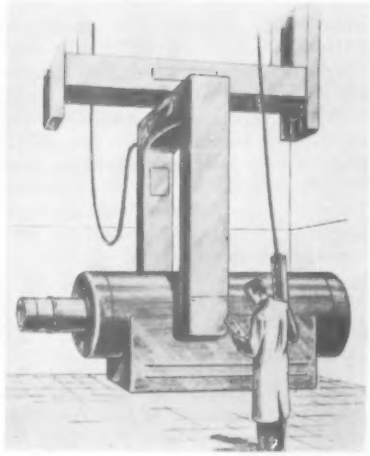
The new facility will generate plasma by electrically heating the gas causing it to ionize. This plasma will then be accelerated to hypersonic velocity through a convergent-divergent nozzle. The resulting ultrahigh-velocity, high-temperature plasma stream will be directed through a test chamber in which exotic material will be tested for thermal shock resistance and aerodynamic reactions. Such experiments will be instructive, for example, in determining the destructibility quotients of missile nose-cone materia'ls.

Consolidated Systems Corp., Monrovia, Calif., an associate company of Allis-Chalmers, will be responsible for the design and layout of over-all system control and instrumentation, including the control console and graphic panel for the plasma jet test stand facility.

Smith Installs 6000 Roentgen X-ray Unit

A powerful X-ray machine—specifically designed for radiography in the metals industry—will be installed at the A. O. Smith Corporation's Milwaukee, Wis., plant this spring. The eight-million electron-volt linear accelerator is now being built for the A. O. Smith Corp. by the High Voltage Engineering Corp., Burlington, Mass. The linear accelerator, or "linac," is designed to "see" through steel more than a foot thick and to furnish photographic proof of the soundness of such metal structures as core barrels for nuclear reactors and high-pressure vessels for the petro-chemical industry.

Warren Hendricksen, general manager of A. O. Smith's Atomic and Process Equipment Div., said that the project would cost $700,000 when completed. The installation, he pointed out, is part of the Atomic and Process Equipment Division's $4 million long-range expansion program which



already has added 80,000 sq ft to the Division's operating space, as well as such new equipment as a 20-ft boring mill and extra large overhead cranes, to permit the fabrication of the largest types of vessels and other capital goods.

"The linac will be an extremely valuable tool to insure even greater reliability, particularly in those products designed to handle nuclear matter or to operate at extremely high pressures," claims Hendricksen.

The linac differs from other radiographic equipment in that it produces its X-rays by "firing" high-energy electrons in a straight line down an evacuated tube. The electrons from the linac move down the tube impelled by traveling radio-frequency waves. These "radar" pulses accelerate the electrons until they approach the speed of light—186,000 miles per sec. At the end of the tube, the electrons strike a tungsten target and produce penetrating X-rays which are beamed upon the material to be examined.

The operating head or tube of the A. O. Smith-High Voltage linac will be 11-ft long and 30-in. in diam, with a 12-in. radiation aperture.

Using eight-million electron-volts (8 Mev), the linac will produce 6000 roentgens per min. While some other types of equipment employ higher voltages, they do not produce X-rays of such high intensity.

The A. O. Smith-High Voltage linac will be equipped with an X-ray source providing a choice of focal spot sizes of 1 and 5 mm. The respective outputs are 1500 and 6000 roentgens per min, making possible the radiographic examination of very thick metals with both speed and clarity.

No other tool saves you so much money in so short a time!

Arcair process for metal removal

The Arcair Torch moves metal. Faster, better, cheaper than any other tool or process. Cuts, gouges, bevels any metal. Under almost any conditions.

ARCAIR PROCESS—The Arcair Torch uses current from your welding machine and special electrodes to melt metal. Ordinary shop air through the Arcair Torch blows away the molten metal. Job is finished, amazingly fast, clean.

SAVES MONEY—The Arcair Process moves metal four, eight, ten times faster. Saves minutes, hours. Eliminates costly finishing equipment. Your men learn to operate the Arcair Torch in 15 minutes. Complete range of hand and automatic torches. There's one that will save you money.

NEED PROOF?—Write us your specific problem. We'll show you how the Arcair Process can save *you* money—fast.

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Lancaster, Ohio

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PERSONNEL

Hartbower Joins Manufacturing Laboratories

Carl E. Hartbower AWS after 18 years of service as a civilian scientist with the government has joined the Physical Metallurgy Div., Manufacturing Laboratories, Inc., Cambridge, Mass., where he will be engaged in welding and mechanical-metallurgy research. Formerly deputy chief of the Materials Sciences Laboratory, Watertown Arsenal Laboratories, he joined the staff of scientists working for the U. S. Army Ordnance Corps in 1952 after having been employed in Washington, D. C., at the Naval Gun Factory as a welding engineer and at the Naval Research Laboratory as a physical metallurgist in welding research. He was transferred to the Army in 1952 to initiate a program in titanium welding research. He later became chief of the Welding Section and then chief of the Metals Joining Branch, responsible for coordinating all U. S. Army welding materials research programs on ferrous and titanium alloys.

Mr. Hartbower graduated from Worcester Polytechnic Institute with a B.S. degree in 1943. In June 1958 he was awarded the Professional Degree of Mechanical Engineer by W.P.I. He was delivered numerous lectures both at AWS section and national meetings, and has published over 30 research papers in the fields of welding engineering, welding metallurgy and mechanical metallurgy.

Linde Advances Galbraith and Helmbrecht

John F. Galbraith AWS has been appointed manager of electric welding development and planning for the Linde Co., Div. of Union Carbide Corp., New York, N. Y. In his new capacity, Mr. Galbraith will direct all technical aspects of Linde's electric welding program, as well as planning.

A graduate of the University of Wisconsin, Mr. Galbraith came to Linde in 1934 in the Engineering Service Dept. After service as a major in the field artillery during World War II, he returned to Linde at the Development Laboratory, Newark, N. J. He was named manager of electric welding development in 1959. His affiliations include the Institute of Management Sciences and the American Ordnance Association.

W. H. Helmbrecht AWS succeeds Mr. Galbraith as development manager at Linde's Electric Welding Development Laboratory in Newark, N. J. Mr. Helmbrecht, a graduate of Stevens Institute of Technology with an M.E. degree, has been with Linde since 1942. A notable mark in his career was his participation in the Manhattan Project in 1944–46.

Citation for Lytton

Charles W. Lytton AWS has been cited as "District Manager of the Year" by The Lincoln Electric Co. of Cleveland, Ohio. He was cited for his leadership and management of the Pittsburgh District which produced a 19% increase in sales over 1959 despite the steel strike and the general recession in heavy fabricating industries.

The citation was made in connection with the company's annual incentive distribution at which time the company cites the outstanding contributions of six or seven individuals.

The citation was presented to Lytton at a special meeting of the Pittsburgh District field engineers with the Regional Manager, Robert Dalzell, and Assistant General Sales Manager, Frank Boucher. The staff of field engineers, Robert Hall, Robert Schuster, Keith Thornberry, Ronald Bauer and Harrison Smitson presented Lytton a personal desk set in recognition of his leadership.

Lytton has been with Lincoln since 1932, joining the staff of field engineers after graduation from Case Institute of Technology. He worked in the Franklin and Buffalo Districts as manager before coming to Pittsburgh in 1952.

C. W. Lytton

C. E. Hartbower

J. F. Galbraith

W. H. Helmbrecht

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Figure the percentage of arc time in an average ten minute period of work. That's the duty-cycle your job requires. Use this important factor in determining which holder you require. Be guided by it as well as by your electrode diameter, amps, and cable size requirements. The capability of a holder to perform your duty-cycle is very important to its long, satisfactory service life.

All the Jackson holders listed are insulated copper-alloy holders. The ST-series holders feature the new trouble-free Sealed Tight cable connection device. For lighter duty-cycles, use Jackson's aluminum-alloy Featherlight electrode holders. See all the Jackson holders at your distributor. Ask for the Jackson Catalog.

Holder Class	Model Number	Electrode Size	Amperage	Cable Size	Duty Cycle
SMALL	AW-C	7/32"	250 300	1 1/0	50%
MEDIUM	A-1 & ST-3	1/4"	300 350	1/0 2/0	50%
LARGE	A-3 & ST-5	3/8"	375 450	2/0 3/0	65%
HEAVY-DUTY	A-3S	3/8"	500	4/0	80%

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J. W. Cunningham

D. K. Rowen

R. W. Cork

D. G. Fike

Airco Names Cunningham

J. W. Cunningham AWS was recently appointed manager of the Air Reduction Sales Co. district sales office in Pittsburgh, Pa., according to an announcement by N. F. Moody, regional sales manager for Airco's eastern region. As manager, Mr. Cunningham will direct the sale and distribution of all Airco products marketed through the Pittsburgh district.

Mr. Cunningham has been associated with Airco since 1947. He first served as a research engineer at Airco's Research Laboratories and subsequently became a field development engineer in 1951.

Three years later he was appointed product sales manager for gas-shielded arc-welding products and processes in the equipment marketing department in New York. Mr. Cunningham was appointed assistant manager of Airco's equipment marketing department in 1959, a position he has held until his present promotion.

A native of Newburgh, N. Y., he was graduated from Rensselaer Polytechnic Institute, Troy, N. Y., in 1942 with a degree in Mechanical Engineering. Following graduation, he entered the U. S. Army and served in the Ordnance Corps until 1946.

Miller Electric Personnel Changes

The Miller Electric Mfg. Co., Appleton, Wis. recently announced the following personnel moves:

E. W. "Gene" Connor has been made regional sales manager for eight western states including Washington, Oregon, California, Idaho, Arizona, Utah, Nevada and Montana.

D. K. "Don" Rowen AWS has been appointed district sales manager under E. W. Connor. His territory consists of Southern California, Arizona and Southern Nevada.

A. H. "Turk" Thurlow will be district sales manager under E. W. Connor, for the states of Washington, Oregon, Idaho and Montana.

R. W. "Ron" Cork AWS is now sales representative for Minnesota, North and South Dakota and part of Iowa.

D. G. "Glen" Fike AWS has been appointed sales representative in the Southeastern Region.

Fred M. Sullivan AWS has been named to the post of technical representative working in the Miller laboratory.

Clarence M. Wieseckel AWS has been appointed assistant to the president in charge of plant operations.

Heading Miller's recently organized Cost Analysis Department is assistant to the president, Margaret M. Harrant.

Townsend Named Executive Vice President

M. W. Townsend, vice president of administration of Handy & Harman, New York, N. Y., has been elected to the newly-created position of executive vice president of the precious metals firm. In addition to his present responsibilities for the accounting and treasurer's departments, he will assume responsibility for the sales department.

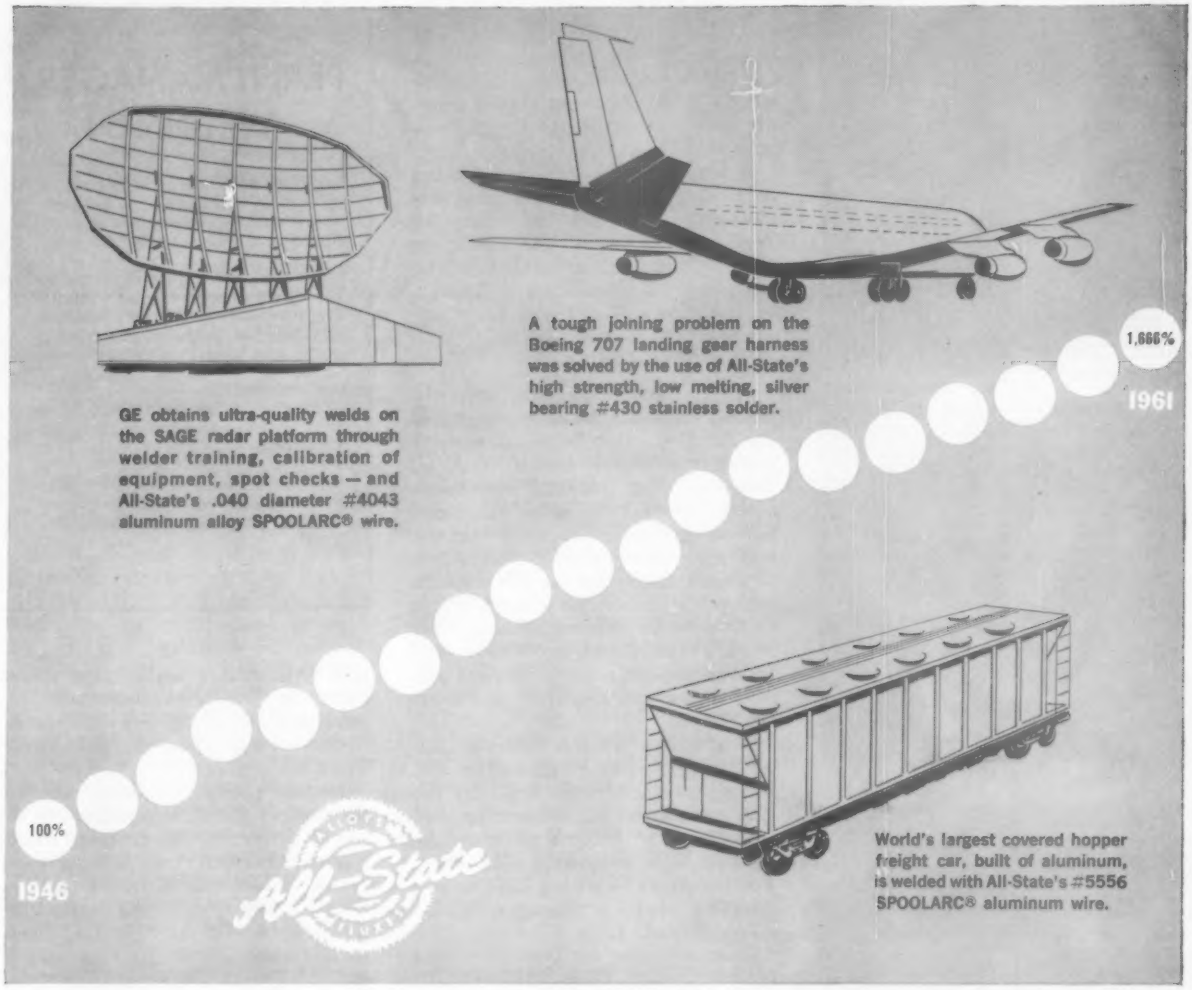
Mr. Townsend joined the sales department of the company in 1946, later becoming sales manager, and then assistant to the president. He has been a director since 1955, and vice president of administration since 1958.

Square D Names W. R. Clarke

Walter R. Clarke was recently appointed to the newly created position of product manager in the

F. M. Sullivan

C. M. Wieseckel


GE obtains ultra-quality welds on the SAGE radar platform through welder training, calibration of equipment, spot checks — and All-State's .040 diameter #4043 aluminum alloy SPOOLARC® wire.
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World's largest covered hopper freight car, built of aluminum, is welded with All-State's #5556 SPOOLARC® aluminum wire.

Thank you for your joining problems

...they helped us grow!

In just 15 years ALL-STATE has become a leading manufacturer of more than 100 specialty alloys and fluxes, thanks to the joining problems put to us by distributors, welders and welding engineers. In the solution of these problems we have won your confidence which helped us bring out new problem-solving specialty solders, brazing and welding rods, and fluxes.

In keeping with the rapid expansion of our quality welding alloys, we announce the addition of silicon bronze, deoxidized copper, aluminum bronze and phosphor bronze to the *Spoolarc*® line of automatic welding wire.

The *Spoolarc*® brand leads production of aluminum alloys at ALL-STATE — the largest manufacturer of aluminum welding wire in the U.S.A.

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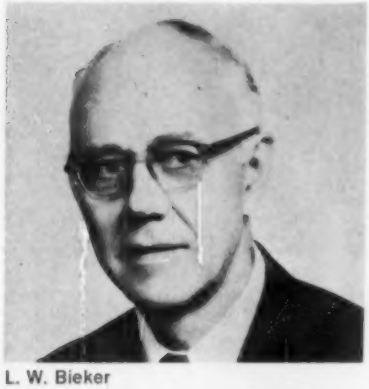
N. F. Moody



L. W. Bieker

A. F. Leach

marketing division of Square D Co., Parks Ridge, Ill. He will have jurisdiction over the product marketing departments of the company's three principal manufacturing divisions, in Milwaukee, Cleveland, and Lexington, Ky.

A native of Chicago, Mr. Clarke received a degree in electrical engineering from the University of Wisconsin in 1939. He has been with Square D since 1941 with the exception of three years' service in the Army Signal Corps.

Moody Advanced

N. F. Moody AWS was recently named regional sales manager of the Air Reduction Sales Co. eastern region in an announcement by A. C. Brown, Jr. AWS, regional vice president. As regional sales manager, Mr. Moody is responsible for the sale and distribution of all Airco products marketed in the eastern region which includes district offices in New Jersey, Massachusetts, New York, Pennsylvania and Ohio. Mr. Moody succeeds A. S. Blodget AWS, who is now vice president, midwestern region.

A graduate of the Cornell University School of Engineering, Mr. Moody started with Airco in the Chicago district in 1946 and in 1948 transferred to Pittsburgh where he worked as a salesman until 1954. For two years following 1954 he was assistant district manager, Philadelphia, and from 1956 to 1958 district manager for Boston. Prior to his present appointment, Mr. Moody was district manager for Philadelphia.

Graver Tank Names Three

L. W. Bieker AWS, Frank Albert, and Walter Chalberg were recently named respectively as project engineer, manufacturing engineer and plant manager for the new $1^1/_2$ million dollar pipe plant currently being constructed in Lockeford, Calif., by Graver Tank & Mfg. Co., a division of Union Tank Car Co.

Bieker, project engineer, will be responsible for the coordination of all engineering procurement and construction activities for the new plant. The manufacturing engineer, Frank Albert, will be reporting directly to Bieker. He has been with Graver, both in engineering and job operations, since 1939.

Walter Chalberg will be Plant Manager in Lockeford and will take up residence there as soon as construction of the new plant begins to take shape. He will act as Resident Engineer during the construction of the plant and installation of machinery. Chalberg has been with Graver since 1953 on field, plant and engineering assignments.

Omark Selects Leach

Austin F. Leach AWS has been appointed manager for product planning and market research at Omark Industries, Inc. Formerly sales manager for the company's stud welding equipment line, Leach in his new position will coordinate additions and modifications to the Omark product line, and will supervise market analysis.

Before coming to Omark, Leach was manager of manufacturing and engineering for the A. L. Smith Iron Co., Cambridge, Mass. Earlier he was manager of equipment planning and product service for

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the Welding Dept. of the General Electric Corp. He is a graduate of the University of Texas.

France Honors Volff

Charles L. Volff, Secretary-General of research at Société L'Air Liquide, Paris, France, has been nominated for the presidency of the Société des Ingénieurs Soudeurs (French Welding Society) for 1961. He will attend the International Institute of Welding and AMERICAN WELDING SOCIETY annual meetings this month in New York City.

Mr. Volff is an AWS member and attended all the general meetings from 1947 to 1955 when he was head of the laboratory of Canadian Liquid Air, Montreal, Canada, an affiliate of Society L'Air Liquide.

Zabriskie Appointed

F. N. Zabriskie has been named assistant manager of sales for the Air Reduction Sales Co. midwestern region it was announced recently by D. F. McCandlish, regional sales manager, midwestern region. In his new capacity, Mr. Zabriskie will coordinate sales of industrial gases and equipment in Airco's midwestern region consisting of the districts of Chicago, St. Louis, Milwaukee, Minneapolis, Davenport, Kansas City and Detroit.

Mr. Zabriskie has been with Airco since 1933, beginning his service in the New York district, located in Jersey City.

Fisher Becomes Sales Manager

William J. Fisher was recently appointed sales manager of The Berkeley Co., Danville, Ill., a subsidiary of The McKay Machine Co. of Youngstown, Ohio, and is in charge of sales of Berkeley automatic fusion welding equipment throughout the world.

He was born and educated in the British Isles, where he attended the National University of Ireland. He has spent over thirty years in the field of welding and allied industries, twenty of which were directly devoted to the design, manufacture and sale of specialized production welding machines.

Prior to joining The Berkeley Co., Mr. Fisher was the midwestern regional engineer, Special Products Dept., Air Reduction Sales Co.

Bastian-Blessing Elevates Augur and Lucas

Three top level changes were voted at the January board of directors meeting by The Bastian-Blessing Co., Chicago, Ill.

Lewis G. Blessing, president since 1931, was elected chairman of the board. Allison L. Augur was elevated from executive vice president to president. Lawrence N. Lucas rises from vice president to executive vice president replacing Augur.

C. L. Volff

Mr. Blessing was co-founder of the Chicago headquartered manufacturer in 1908. Augur joined the company in 1923 as assistant sales manager of the RegO valve division. Lucas came in 1937 as assistant sales manager of the fountain-food equipment division.

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Weigert Accepts Penn State Appointment

On February 1st, K. M. Weigert AWS joined the staff of the Dept. of Industrial Engineering at Pennsylvania State University as an assistant professor. He will be teaching courses in metal working and joining. He will also be devoting considerable time to research.

Merriman Named Manager

R. H. Merriman AWS was recently appointed district manager of the Air Reduction Sales Co. Philadelphia office. As district manager, Mr. Merriman is responsible for the sale and distribution of all Airco products marketed through the Philadelphia facilities located at Allegheny and 17th St. Mr. Merriman succeeds Mr. N. F. Moody as Philadelphia district manager.

A graduate of Tufts College, Mr. Merriman joined Airco in 1937 as a salesman in the New York district. Except for army service from 1943 to 1946, he continued in this position until 1949 when he was transferred to the Boston district. In 1954 he became assistant manager, metropolitan New York district and in 1958 was made district manager of Buffalo, N. Y., a position he held up to his present appointment.

Mr. Merriman is a member of the AMERICAN WELDING SOCIETY, the Rotary Club of Buffalo, the Chamber of Commerce, the Buffalo Athletic Club and the East Aurora Country Club.

Armour Advances Schwartzbart and Van Thyne

The appointments of Harry Schwartzbart AWS and Ray J. Van Thyne as assistant directors of metals research at Armour Research Foundation have been announced by Dr. Donald J. McPherson, ARF metals research director.

Schwartzbart became affiliated with ARF in 1951, and for the past five years has served as supervisor of welding research. Before joining the Foundation, he served three years as a research metallurgist for the National Advisory Committee for Aeronautics, Cleveland.

Van Thyne is a specialist in high temperature alloys and the application of metals to special atomic energy problems. He became associated with ARF in 1960 and for the past four years has served as supervisor of reactor metallurgy.

Champion Appointed Vice President

David J. Champion AWS was recently appointed vice president of The Champion Rivet Co., Cleveland, Ohio, manufacturers of rivets, upset forgings and special welding electrodes. Formerly sales manager of the Cleveland firm, David Champion is the son of T. Pierre Champion, company president and grandson of the late David J. Champion, who founded the company in 1895.

A graduate of Notre Dame University and Navy veteran of the Pacific Theater during World War II, Champion began his career in the company's East Chicago plant in production control. Later he was a district salesman in Chicago and Cleveland. Champion spent two years in Mexico City as general manager of Champion de Mexico, a subsidiary company.

Eder to General Sales Manager

John W. Eder, Jr., was recently appointed general sales manager of Chicago Eye Shield Co., Chicago, Ill. Eder, a graduate of the University of Southern California School of Business Administration formerly was assistant sales manager of the company.

Arcos Advances Light

R. David Thomas, Jr. AWS, president of Arcos Corp., has announced the appointment of John K. Light AWS as assistant to J. E. Norcross AWS, executive vice-president. Prior to this appointment, Mr. Light held positions with Arcos Corp. as manager of private brands, assistant sales manager and district manager in New England.

Postlewait Appointed

George R. Postlewait has been appointed Western Regional Manager for the RegO Plant Equipment Div. of The Bastian-Blessing Co. in the states of Arizona, California, Nevada, Oregon, Washington and Western Idaho. This appointment is concurrent with the retirement of Earl M. Evleth.

Mr. Postlewait has been active in the gas industry for many years; including eight years as Bastian-Blessing District Manager for Ohio, Pennsylvania and West Virginia.

Joerger Named District Manager

William C. Joerger has been named district manager in the South Niagara Frontier of New York for Eutectic Welding Alloys Corp., Flushing, N. Y. He was previously a Technical Representative in the area.

Eddy Appointed by Sellstrom

Charles R. Eddy has been appointed eastern factory sales representative for Sellstrom Manufacturing Co., Palatine, Ill., manufacturers of face and eye protective equipment. Serving the east coast territory from Maine to Virginia, he will call on distributors of welding and safety products.

OBITUARY

Pierre Balteau

Pierre Balteau, 41, president of the Balteau Electric Corp., Stamford, Conn., was killed February 15th in the crash of a Sabena airliner near Brussels. Mr. Balteau was returning to his home in Liege, Belgium, following a visit to the United States.

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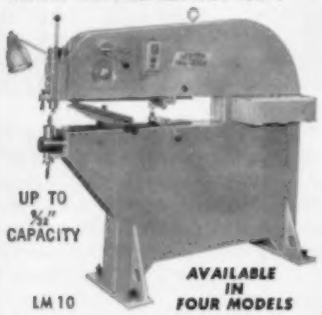

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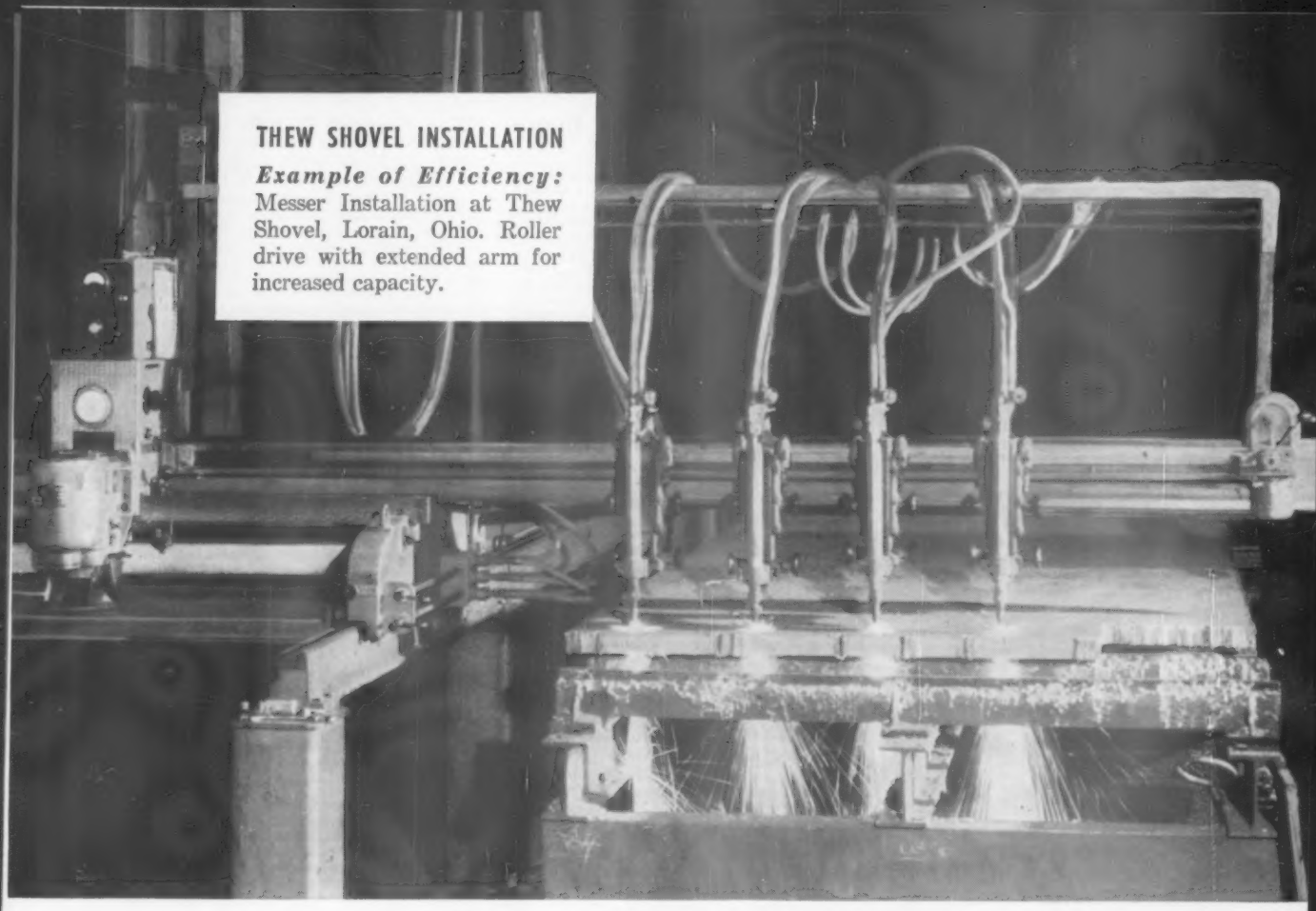

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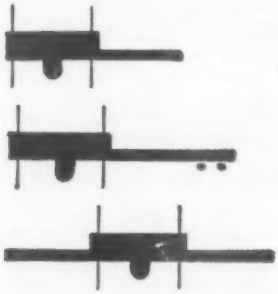

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Abstracts of Current PATENTS

prepared by Vern L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington, D. C.

2,922,020—Method and Apparatus for Forming Lap Welded Tubing—Arthur L. Andrew, Cleveland, Ohio, assignor to Magnetic Heating Corp., New Rochelle, N. Y., a corporation of New York.

In this method, a longitudinally extending lapped seam is provided in tubing and the method includes advancing the tubing with the edges which are to be lap welded together positioned in overlapped relation and with a V-shaped gap therebetween. The apex of the gap is at the desired weld point. Pressure is applied to the overlapped edge portions at the region of the weld point, and high-frequency current is applied to bands of the opposed surfaces of the edge portions within the V-shaped gap in advance of the weld point so that current flows from the electrical supply contacts along edge bands of the overlapped tubing portions to and from the weld point to heat such bands to welding temperature by the time they reach the weld point.

2,922,023—Electric-arc Process and Apparatus—Robert L. Hackman, Morris Plains, and Raymond P. Sullivan, Jersey City, N. J., assignors to Union Carbide Corp., a corporation of New York.

In this process, a pilot high-pressure arc is ignited between spaced electrodes and the pilot arc is applied to a workpiece which is electrically neutral with respect to the arc. Then the pilot arc is electrically transferred to the workpiece by applying substantially the same relative potential at one of the electrodes to the work piece.

2,922,024—Electric-arc Welding—Robert Arthur Cresswell, London, England, assignor to The British Oxygen Co. Ltd., a corporation of Great Britain.

Cresswell's method relates to an inert-gas-shielded electric arc-welding process wherein an inert gas is fed to the welding zone in such a manner that the major portion of such gas forms an annular curtain surrounding but spaced from the electrode and the arc and directed toward a colder part of the workpiece. The remainder of the inert gas is fed to the space within the outer curtain of gas to flow in a separate path and form an inner gas curtain immediately surrounding the electrode and the arc.

2,922,025—Constant-pressure Multiple-wheel Welding Head—John R. Fullerton and Lawrence E. Leech, San Diego, and Donald L. Heyser, Lemon Grove, Calif., assignors to Ryan Aeronautical Co., San Diego, Calif.

The present patent relates to a welding head including a long stroke cylinder having a piston therein which has a rigid support member secured thereto. A plurality of fluid pressure cylinders are adjustably mounted on the support member and each has a piston therein. A wheel electrode is operatively connected to each of these last named pistons. A single source of fluid pressure is connected to these last named cylinders to maintain equal and constant pressures between each electrode and the work surface. Other pressure means connect to the first-named cylinder to move the electrodes collectively into contact with a work surface.

2,922,026—Spot-welding Apparatus—Karl Berthold Ernst Arno Hauptmann, Hamburg-Othmarschen, Germany, assignor to Wilhelm Heine (trading as Heine Kommandit-Gesellschaft), Hamburg-Altona, Germany.

In this patent, a spot-welding apparatus is disclosed and it includes a transformer having a three-legged core including a middle leg and two outer legs. A primary winding is provided on the middle leg and a secondary winding is also present. Tong-like electrode arms are carried by the transformer and form part of the secondary winding which links the flux of the middle core leg with at least one integral turn and also the flux of one of the outer core legs to provide a total nonintegral number of linking turns with respect to the flux in the middle core leg.

2,922,027—"Swing-head Electrode Holder"—Charles J. Dumais, Woonsocket, R. I.

Dumais' patent relates to an electrode holder having a special movable head and jaw assembly provided therein.

2,922,028—Electric-arc Electrodes—Thomas E. Butler, Niagara Falls, and John A. Persson, Kenmore, N. Y., assignors to Union Carbide Corp., a corporation of New York.

An electric arc electrode made from pure tungsten and thoriated tungsten parts is provided in this patent. The pure tungsten supports and conducts the arc current to the thoriated tungsten part from which the arc is drawn. The thoriated tungsten contains about 2% of thoria.

2,922,868—Gas-shielded Internally-Cooled Electrode Welding Torch—Robert Linford Hackman, Morris Plains, and Glenn W. Oyler, Springfield, N. J., assignors to Union Carbide Corp., a corporation of New York.

This novel gas-shielded arc-welding torch is for use with high-density reverse-polarity current. In the torch, a restricted cross-sectional area is provided near the arcing tip to increase the velocity of cooling fluid in contact therewith. The torch is so set up that the wall of the arcing tip is held substantially in equilibrium between the cooling effect of the cooling fluid contacting it, and the melting-off effect of the high-density reverse-polarity current on the arcing tip.

2,922,869—Plasma-stream Apparatus and Methods—Gabriel M. Giannini, Newport Beach, and Adriano C. Ducati, Corona Del Mar, Calif., assignors to Plasmadyne Corp., Santa Ana, Calif., a corporation of California.

This patent covers a plasma-jet torch apparatus which includes a metal nozzle with a nozzle opening therein, and a back electrode having an arcing portion disposed opposite the nozzle opening and spaced from such opening a distance less than four times the minimum diameter of the opening. Other means define a gas pressure chamber the side wall of which is a surface of revolution about an axis through the nozzle opening. This chamber has a diameter at least two times the minimum diameter of the opening and the chamber communicates with the arcing portion and with the opening. A member is present to pass gas tangentially into the gas pressure chamber for vortical flow therein and subsequent expansion through the nozzle opening.

2,922,871—Gas-shielded Arc Welding—Robert L. Hackman, Morris Plains, Raymond P. Sullivan, Jersey City, and Roscoe R. Lobosco, Fanwood, N. J., assignors to Union Carbide Corp., a corporation of New York

In this arc-welding system, a torch is provided that includes a main electrode and an auxiliary electrode. A negative terminal of a direct current welding source is connected to the main electrode and the positive electrode thereof is connected to the work while a direct-current pilot-arc source has its negative terminal connected to the main electrode and a positive terminal to the auxiliary electrode. A pilot-arc voltage response relay is connected in the system. The relay is operable to transfer a pilot-arc from the main electrode back to the auxiliary electrode when the pilot-arc voltage drop between the main electrode and the work is increased to a predetermined value after the welding current circuit is broken.

2,923,621—Nickel-base Brazing Alloy Containing Manganese—George Sidney Hoppin III, Fairfield, Ohio, assignor to General Electric Corp., a corporation of New York.

This patent is on an improved nickel-base brazing alloy made from about 10 to 30 parts by weight chromium, about 8 to 12 parts by weight silicon and about 7 to 15 parts by weight manganese. The balance of the alloy essentially comprises nickel and impurities.

2,923,807—Process for Continuously Manufacturing Tubes—Erich Hormann, Dusseldorf-Eller, Germany, assignor to Firma Phoenix-Rheinrohr A. G., Vereinigte Hutten- und Rohrenwerke, Dusseldorf, Germany.

This patent is on a process for continuously manufacturing ferrous tubing having a copper content capable of migrating to edges to be welded when subjected to conventional hot-rolling temperatures. In the process, a plurality of blocks are welded together end-to-end and then are subjected to special rolling conditions to form a band from the bar. Longitudinal strip-portions of a width of only a few millimeters along opposed side edges of the band are heated to a welding temperature and the band is curved transversely so that the heated edges thereof can be continuously welded together to form a tube. This tube is then continuously drawn and reduced in size to the final dimensions desired.

2,923,809—Arc Cutting of Metals—Kenneth James Clews, Walsall, and Godfrey Brian Roberts, Brewood, England, assignors to Marston Excelsior Ltd., London, England, a corporation of Great Britain.

This new arc torch includes a nonconsumable electrode and a nozzle having a passage coaxial with the electrode and through which the electrode can extend so that a pilot discharge can be established between the electrode and a metal workpiece without harming the nozzle. Other means provide relative movement between the electrode and the nozzle so that a main arc struck between the electrode and workpiece passes through the passage. The passage is sufficiently constricted to wall-stabilize a portion of the length of the main arc. Other means direct a gaseous stream through the passage toward the workpiece to shield the electrode during use.

2,923,810—Flying Multiple-spot Welding Machine and Actuating Means Therefor—George Molnar, Warren, Ohio, assignor to the Taylor-Winfield Corp., Warren, Ohio, a corporation of Ohio.

Molnar's patent is on a flying multiple-spot machine for completing a plurality of welds between moving workpieces on the fly and the apparatus includes a carriage mounted on a base and movable thereon in the direction of movement of the workpieces. A plurality of welding means are mounted on the carriage in a pair of longitudinally extending transversely spaced rows and these welding means are mounted on a pair of housings that are pivotally positioned on the carriage for pivotal movement away from the workpieces to cover or expose such work pieces.

Current Welding LITERATURE

For copies of articles, write directly to publications in which they appear. A list of addresses is available on request.

Aluminum

Argon-Arc Spot Welding of Commercial Purity Aluminium, L. M. Gourd and F. W. Copleston. *Welding & Metal Fabrication*, vol. 28, no. 9 (Sept. 1960), pp. 368–374.

Beams and Girders

Fatigue Strength of Beams with Stiffeners Welded to Tension Flange, T. R. Gurney. *Brit. Welding Jnl.*, vol. 7, no. 9 (Sept. 1960), pp. 569–576.

Bicycles

Bicycle Production in Japan, R. E. Green. *Machy.* (Lond), vol. 97, no. 2486 (July 6, 1960), pp. 46–56.

Brazing

Infrared Simplifies Brazing. *Steel*, vol. 146, no. 22 (May 30, 1960), pp. 84–85.

Silver Brazing Has Many Talents, J. S. Fullerton. *Can. Machy. & Metalworking*, vol. 71, no. 9 (Sept. 1960), pp. 122, 124, 126, 128.

Electroslag Welding

New Machine Welds Steel Sections Rapidly, Economically. *Purchasing*, vol. 48, no. 6 (Mar. 14, 1960), pp. 94–95, 98.

Practical Application of Electroslag Welding, B. K. Jellberg. *Welding & Metal Fabrication*, vol. 28, no. 9 (Sept. 1960), pp. 347–356.

Heat Exchangers

Automatic CO_2-Mig Welding Increases Heat Exchanger Production Up to 65%. *Welding Engr.*, vol. 45, no. 8, (Aug. 1960), pp. 44–45.

Hydrogen Content

Hydrogen in Welding—Houdremont Lecture 1959, P. G. Bastien. *Brit. Welding Jnl.*, vol. 7, no. 9 (Sept. 1960), pp. 546–557.

Nondestructive Testing

18 Mev Mobile Betatron, W. H. Laws, F. Malsch, R. Schittenhelm and P. H. Wagner. *Welding & Metal Fabrication*, vol. 28, no. 9 (Sept. 1960), pp. 357–361.

Nuclear Reactors

Fuel-Channel Sleeves. *Aircraft Production*, vol. 22, no. 9 (Sept. 1960), pp. 328–334.

Oxygen Cutting

Powder Cutting of Stainless Steels Using Natural Gas, I. D. Davydenko, G. F. Kulicharko and M. M. Eremenko. *Welding Production* (translation of *Svarochnoe Proizvodstvo*), (Oct. 1959), pp. 98–104.

Pipe Fittings

Design of Welded Pipe Fittings, P. H. R. Lane and R. T. Rose. *Brit. Welding Research Assn.* (Nov. 1959), 49 pp.

Pipe Branch Connections, P. H. R. Lane. *Engineering*, vol. 190, no. 4929 (Oct. 7, 1960), pp. 490–492.

Power Supplies

How to Connect Aluminum Welding Cable, C. G. Sorflaten and R. A. Burkhardt. *Welding Eng.*, vol. 45, no. 7 (July 1960), pp. 25–27.

New Welder Busway Distribution System, L. E. Fisher and R. W. Dailey. *AIEE—Trans.*, vol. 79, Pt. 2 (Applications & Industry), no. 49 (July 1960), pp. 203–213; (discussion) 213–215.

Using Voltage Spikes in Resistance Welding, S. C. Rockafellow. *Electronics*, vol. 33, no. 30 (July 22, 1960), pp. 69–71.

Radar

Fabrication of Height-Finding Radar Equipment, C. Waller and E. Morley. *Welding & Metal Fabrication*, vol. 28, no. 9 (Sept. 1960), pp. 340–346.

Quality Control Is Must When Welding Radar Antennas, W. R. Schneider. *Welding Engr.*, vol. 45, no. 9 (Sept. 1960), pp. 58–60.

Radio Equipment

Ultrasonic Welding of Electronic Components, W. C. Potthoff, C. F. DePrisco and W. N. Rosenberg. *IRE Int. Convention Rec.*, vol. 8, pt. 6 (Component Parts, etc.), 1960, pp. 11–18.

Railroad Cars

Short Runs Are Big Business in Rail Cars, R T. Berg. *Am. Mach/Metalworking Mfg.*, vol. 104, no. 18 (Sept. 5, 1960), pp. 106–108.

Refineries

Welding Lends Oil Industry Hand in Vessel Construction, C. J. Ascenzi and R. A. Near. *Welding Engr.*, vol. 45, no. 8 (Aug. 1960), pp. 42–43.

Soldering

Soldering Stainless Steels, D. C. Stock and W. J. Smellie. *Welding & Metal Fabrication*, vol. 28, no. 4 (Apr. 1960), pp. 160–161; see also *Metal Industry*, vol. 96, no. 14 (Apr. 1, 1960), pp. 274–275.

Resistance Welding

Spot Welding Low-Carbon Steel Sheet. *Sheet Metal Industries*, vol. 37, no. 401 (Sept. 1960), pp. 661–666, 670.

Stainless Steel

Effect of Phosphorus on Elevated-Temperature Strength and Weldability of Some Low-Carbon Austenitic Stainless Steels, G. R. Rundell and R. J. Raudebaugh. *Am. Soc. Metals*—Preprint no. 194 (for meeting Oct. 17–21, 1960), 18 pp.

Stainless Steel Is Easily Welded, R. J. Franz. *Welding Engr.*, vol. 45, no. 8 (Aug. 1960), pp. 46, 48, 50.

Steel Structures

Diaphragm Action in Light Gage Steel Construction, A. H. Nilson. *Am. Iron & Steel Inst.*—Paper for meeting Oct. 13, 1960, 28 pp.

Surfacing

Hardsurfacing Guide, V. Peters. *Coal Age*, vol. 65, no. 9 (Sept. 1960), pp. 88–94.

Hard Surfacing of Blast Furnace Bells and Hoppers, R. Fluck and C. W. Dunn. *Iron & Steel Engr.*, vol. 37, no. 9 (Sept. 1960), pp. 183–189.

Tanks

Automatic Welding of Large Storage Tanks. *Welding & Metal Fabrication*, vol. 28, no. 8 (Aug. 1960), pp. 309–315.

Thermocouples

Capacitor Discharge Welding. *Welding & Metal Fabrication*, vol. 28, no. 4 (Apr. 1960), pp. 155–157.

Transistors

Cold Pressure-Welding and Its Influence on Device Design and Manufacture, D. Boswell and R. Humphrey. *Instn. Elec. Engrs.—Proc.*, vol. 106, Pt. B, Supp no. 15 (May 1959), pp. 454–458.

Steel Weldability

How to Weld T-1 Steel. *Welding Engr.*, vol. 45, no. 4 (Apr. 1960), pp. 38–40.

Ultrasonic Welding

Methods of Improving Weld Quality by Ultrasonically Vibrated Weld Pools, A. A. Erokhin and L. L. Silin. *Engrs.' Digest*, vol. 21, no. 7 (July 1960), pp. 81–82.

Welding Quality Control

Quality Control of Welded Fabrication, S. Rowden. *Sheet Metal Industries*, vol. 37, no. 401 (Sept. 1960), pp. 667–670.

New Literature

AWS Publishes Bibliographies for 1960

The AMERICAN WELDING SOCIETY has announced the publication of the 1960 Supplement to the AWS Bibliographies. The original publication contained bibliographies of articles which appeared in THE WELDING JOURNAL from 1937 through 1957 and each year a Supplement is compiled listing the previous year's articles.

The Bibliographies previously issued listed articles under 28 subject headings. The current Supplement contains listings of all articles appearing in the JOURNAL from January through December 1960. The complete Bibliographies thus provide a record of all articles on welding, welding research and related subjects which have appeared in the SOCIETY's magazine from 1937 through 1960.

The supplement has been designed for use as issued or as supplementary material to bring previously issued AWS Bibliographies up-to-date. The format is identical and entries under a given subject are contained on one or more pages. Each page is punched to facilitate insertion into the original Bibliographies under the respective subject headings.

The compilation of these data is performed as a service to industry to eliminate the time consuming examination of technical literature in the search for information on a given subject.

Copies of the "1960 Supplement to the AWS Bibliographies" may be obtained at a cost of $1.50 from the AMERICAN WELDING SOCIETY, Technical Dept., 33 W. 39th St., New York 18, N. Y.

Metallizing Symbols

American Standard Metallizing Symbols, Y32.12-1960, has been approved by the American Standards Assn. and published by The American Society of Mechanical Engineers, in collaboration with the AMERICAN WELDING SOCIETY.

The use of metallizing to obtain a desired dimension or finish has reached the point where it is now recognized as an engineering tool that is equally suitable for new fabrication as well as repair.

This standard provides a means for the conveying of information from the design office to the shop, or from one distant location to another with the assurance that the specified requirements will be met.

The information is divided into four main sections: basic symbols, surface preparation symbols, supplementary symbols and applications.

The symbols are intended to specify on drawings the extent and nature of each operation—surface preparation, spraying, etc.—that is required to obtain the finished part but not to provide details of procedures to be used. Proper control of these operations can be maintained only by the use of written, proven procedures in the shop.

The standard, based on symbols used in the U. S. and Canada, was developed by a task group of the AMERICAN WELDING SOCIETY for the ASA Committee on Graphical Symbols and Designations, Y32, under the co-sponsorship of the American Institute of Electrical Engineers, and The American Society of Mechanical Engineers.

Copies of "American Standard Metallizing Symbols, Y32.12-1960," are available at $1 each from the American Standards Assn., Dept. PR 189, 10 E. 40th St., New York 16, N. Y., or from The American Society of Mechanical Engineers, 29 W. 39th St., New York 18, N. Y.

Resistance Welding Data

A new booklet (IC 2-1960) on "*Resistance Welding Control*" has been published by the National Electrical Manufacturers Assn.

The publication contains information on definitions, ratings, tests, service conditions, connections, enclosures, magnetic and electronic welding contracting, controls, time-accuracies, frequency converter controls, accessories, applications, static switching control devices, type "J" controls, symbols and device designations.

Copies are available from the National Electrical Manufacturers Assn., 155 E. 44th St., New York 17, N. Y., for $1 per copy.

Stainless Steel Welding Techniques

The Lincoln Electric Co., Cleveland 17, Ohio, has announced the availability of information concerning techniques for welding stainless steel in Bulletin 7300.2 entitled "Arc Welding Stainless Steel." This bulletin gives physical properties, structure and welding characteristics of the different types of stainless steels. It also has a chart listing deposit properties and electrode recommendation tables for the different types of stainless steel.

For your free copy, circle No. 60 on Reader Information Card.

Electronic Information Searching

An 8-page brochure describing the ASM's new electronic system of searching metallurgical and related literature for specific information on subjects is available from the American Society for Metals, Metals Park, Novelty, Ohio. It discusses the mechanized way to reduce research costs and increase accuracy, speed and effectiveness. The brochure shows how subscribers may receive, every two weeks, information on anything published in the preceding two weeks on their field of interest.

For your free copy, circle No. 61 on Reader Information Card.

Brazing Data

A new $8^1/_2$ x 11 two-page Nicrobraz engineering data sheet (No. 2.1.4) describing W. G. Nicrobraz brazing alloy is now available from Stainless Processing Div., Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich.

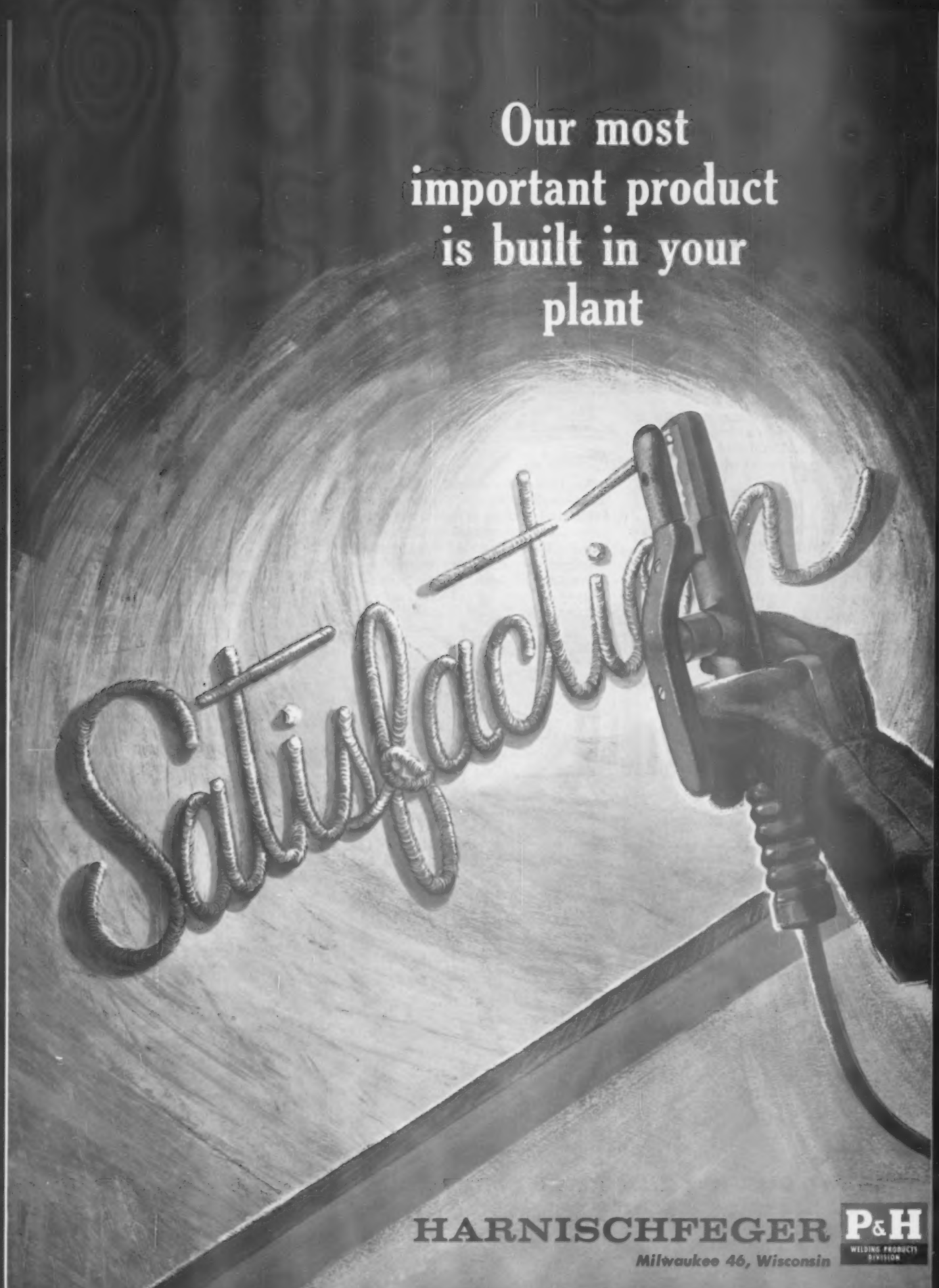
The literature describes the material and lists its engineering and brazing properties. Recommended uses are listed and an illustrated typical case history application example is also included.

For your free copy, circle No. 62 on Reader Information Card.

Heat Treatment Book

Copies of "Heat Treatment and Properties of Iron and Steel," by Thomas G. Digges and Samuel J.

For details, circle No. 32 on Reader Information Card →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Rosenberg, National Bureau of Standards Monograph 18, issued Oct. 3, 1960, 40 pages, may be ordered from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at a cost of $.35 each.

This monograph has been prepared to answer such inquiries and to give, in simplified form, a working knowledge of the basic theoretical and practical principles involved in the heat treatment of iron and steel. The effects of various treatments on the structures and mechanical properties of these materials are described. Some theoretical aspects and technical details are discussed only briefly or omitted entirely for better understanding of the general subject.

The monograph also contains a complete listing of all current structural, tool and stainless steels, and their recommended heat treatments.

Resistance-Welding Transformers

Kirkhof Manufacturing Co., 2450 Buchanan Ave., S. W., P.O. Box 1, Grand Rapids 7, Mich., has published an 8-page illustrated bulletin giving construction details and operating characteristics of their line of epoxy-insulated resistance-welding transformers.

For your free copy, circle No. 63 on Reader Information Card.

Steel Tubing Booklet

Those associated with the design, manufacture or purchase of equipment involving the use of mechanical and hydraulic tubing will be interested in a new brochure published by the Tubular Products Div. of The Babcock & Wilcox Co., Beaver Falls, Pa. The 8-page booklet, designated T-459, covers electric resistance-welded carbon-steel mechanical tubing, and other B&W products.

For your free copy, circle No. 64 on Reader Information Card.

Welding Foil

Air Reduction Sales 150 E. 42nd St., New York 17, N. Y., has made available reprints of an article by John Campbell, titled "Welding of Foil." The article (ADR 125) was delivered as a paper before the AMERICAN WELDING SOCIETY convention, and appeared in the December 1959 issue of the WELDING JOURNAL.

Illustrated with graphs and photographs, the article provides complete information on the control of process variables for the successful welding of foil. Problems and critical variables in the welding foil by the tungsten-arc process are investigated under the three main sections in Campbell's article. The headings are titled, inherent variables affecting welding; requirements for satisfactory welding of foil; and effect of welding variables on joint properties.

For your free copy, circle No. 65 on Reader Information Card.

Use of Electrodes In Varied Industries

A new 8-page folder (Bulletin A-3) containing case history reports on the successful use of welding electrodes in three varied industries is available from The McKay Co., 1005 Liberty Ave., Pittsburgh, 22, Pa.

One report outlines how McKay engineers developed a special welding electrode to help solve a costly nuclear Ramjet problem for a supplier working on Project Pluto, the highly classified government space program.

Another case history shows how a major steel producer extended the service life of blooming mill guides 900% through hard surfacing.

The third report takes the reader into the plant of one of the West Coast's largest pump weldment fabricators to see how this firm gets consistently high-quality welds by using stainless steel electrodes.

For your free copy, circle No. 66 on Reader Information Card.

Condensed Tube Catalog

Amperex Electronic Corp., 230 Duffy Ave., Hicksville, L. I., N.Y., announces a new, 25-page, condensed tube catalog.

The catalog contains descriptions and basic specs on the full line of Amperex Tubes, consisting of: cold cathode trigger tubes, entertainment and audio tubes, ignitrons, indicator tubes, klystrons, magnetrons, noise diodes, power tubes, photomultiplier tubes, "Premium Quality" (PQ) tubes, radiation counter tubes, rectifier diodes, subminiature tubes, thyratrons (hydrogen, mercury vapor and inert gas types), traveling wave tubes, UHF special purpose tubes, and voltage reference and regulator tubes.

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Plasma Cutting Torch Bulletin

Bulletin C-101 published by Thermal Dynamics Corp., Lebanon, N. H., describes a new metal cutting torch that utilizes the principle of

ultrahigh temperature plasma to cut steel, stainless steel, aluminum, copper, cast iron or any other metal up to 4-in. thick or beyond.

For your free copy, circle No. 68 on Reader Information Card.

Welding Connections Catalog

A new and larger 1961 Welding Connections Catalog has been issued by Western Enterprises, Inc., Bay Village 40, Ohio. Included in the 20-page, two-color catalog are more than 200 fitting illustrations, a numerical index, prices, and a picture story of Western's operations.

For your free copy, circle No. 69 on Reader Information Card.

Hydraulic Systems

The application of packaged hydraulic systems to solve a wide range of process control problems is the subject of a new 6-page bulletin announced by Vickers Inc., Detroit 32, Mich., Div. of Sperry Rand Corp. Whether used for valve control or power transmission, these systems set the standard for simplicity of installation and reliability in operation.

For rapid actuation of large process steam control valves, hydraulic powering is the single answer to smooth control, positioning stability, freedom from vibration and excellent frequency response. When variable speed power transmission is needed for driving process pumps, machinery, mixers and fans, fluid power drives best satisfy the requirements.

Bulletin I-5802 includes numerous illustrations showing typical packaged hydraulic systems and installations. Advantages of hydraulics in process control as listed, and standard components are illustrated.

For your free copy, circle No. 70 on Reader Information Card.

Grinding Wheel Standards

The Grinding Wheel Institute, 2130 Keith Bldg., Cleveland 15, Ohio, announces approval by the American Standards Association of new ASA standard specifications for shapes and sizes of grinding wheels, and has issued the new publication "American Standard Specifications for Standard Shapes and Sizes of Grinding Wheels, B74.2-1960."

An American Standard is intended as a guide to aid the manufacturer, the consumer and the general public. It implies a consensus of those substantially concerned with its scope and provisions. These new standards classify, according to twelve end use categories, the shapes and sizes of grinding wheels which are considered standard by industry. A shape and size of a wheel has been included only after determining on the basis of sound engineering practice, whether or not it was designed, dimensionally, to perform the job for which it was intended.

The publication of these new standards supplements and replaces the prior publication "Standard Shapes and Sizes of Grinding Wheels, Simplified Practice Recommendations, R45-57."

For your free copy, circle No. 71 on Reader Information Card.

Connections in Welding

Electrical connections that run hot mean trouble for a welding system, according to a new bulletin, "Welding's Vital Links," issued by J. B. Nottingham & Co., 441 Lexington Ave., New York 17, N. Y.

Attention to connections will protect the heavy investment in welding equipment and skilled welders, the publication explains. Poor connections not only waste power but also, especially in the newer and more critical processes like tungsten arc and consumable electrode welding, can impair weld quality.

Thirteen ways to judge the quality of welding system connections are listed. Electrically and mechanically, each connection should be equivalent of the cable it joins, the bulletin points out.

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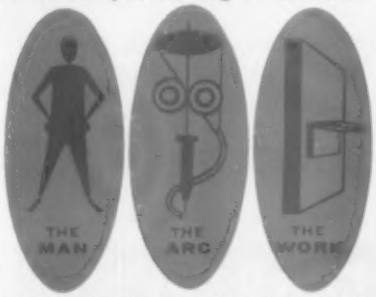

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Soldering and Brazing

A-four page, two-color brochure describing new "economic automation processes" in soft soldering and silver brazing has just come off the press and is available from Fusion Engineering, 17921 Roseland Ave., Cleveland 12, Ohio.

The new brochure describes a reportedly unique method of automating production soldering and brazing operations with paste alloys. It also describes briefly three series of paste materials available, and gives four case history examples of *cost savings* achieved through installation of "automatic," "semiautomatic" and "manual" equipment.

In "automatic" installations, reported cost savings of $25,000 and $18,000 per year are illustrated with investments of $3500 and $2500, respectively. With "semiautomatic" installation savings of $10,000 per year with an equipment investment of $450 are shown.

The brochure also incorporates a partial list of users as well as typical customer parts which have been automatically soldered using the Fusion process.

For your free copy, circle No. 73 on Reader Information Card.

Multigun Welding Machines

A new issue of Tips and Dies, Vol. 4, No. 1, has just been made available from The Federal Machine and Welder Co., Warren, Ohio. In color, the four page pamphlet describes and illustrates fourteen multi-gun welding units, modern methods for mass production of fabricated parts.

For your free copy, circle No. 74 on Reader Information Card.

Silicones

A new booklet on silicones containing the most recent and advanced information on these chemicals has just been issued by the Silicones Div., Union Carbide Corp., 270 Park Ave., New York 17, N. Y., as an aid to engineers and technical personnel.

Graphically illustrated with photographs, charts and graphs, the booklet goes into detail about what silicones are, describes their manifold uses for consumer and industrial products, and suggests ways in which they can be adapted to a host of new applications by the design, engineer or product development manager. Of special significance is the series of charts covering the properties and features of Union Carbide Silicone fluids, resins, rubber compounds, water repellents, antifoams and emulsions, and their adaptability for use by the aviation, automotive, chemical, electronic, rubber, paint, paper, textile, glass, metal working and other industries.

For your free copy, circle No. 75 on Reader Information Card.

New Brazing Alloy

A new 8½ x 11 two-page engineering data sheet (No. 2.1.12) describing Nicrobraz 160 brazing alloy is now available from Stainless Processing Div., Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich.

The literature describes the material and lists its engineering and brazing properties. Recommended uses are listed, and an illustrated typical case history application example is also included.

For your free copy, circle No. 76 on Reader Information Card.

Scandinavian Research Guide. Paper cover, 2 vols., 5¾ x 8¼ in., vol. I, 687 pp., vol. II, 486 pp. published by the Scandinavian Council for Applied Research, Blindern, Norway. Price $10.

This two-volume edition is intended as a directory of research institutes within technology and science, exclusive of life sciences, in Scandinavia.

The directory is the result of a critical need to know who is doing what and where in science and technology. It is an attempt to bridge communication voids among the world's scientists.

Volume I contains a listing of pertinent information about research institutes and laboratories. Volume II, which has colored-page sections for easy use, lists central research organizations; universities, colleges and institutes of technology; scientific societies and their publications; central scientific and technical libraries and information and documentation centers; productivity centers and a bibliography.

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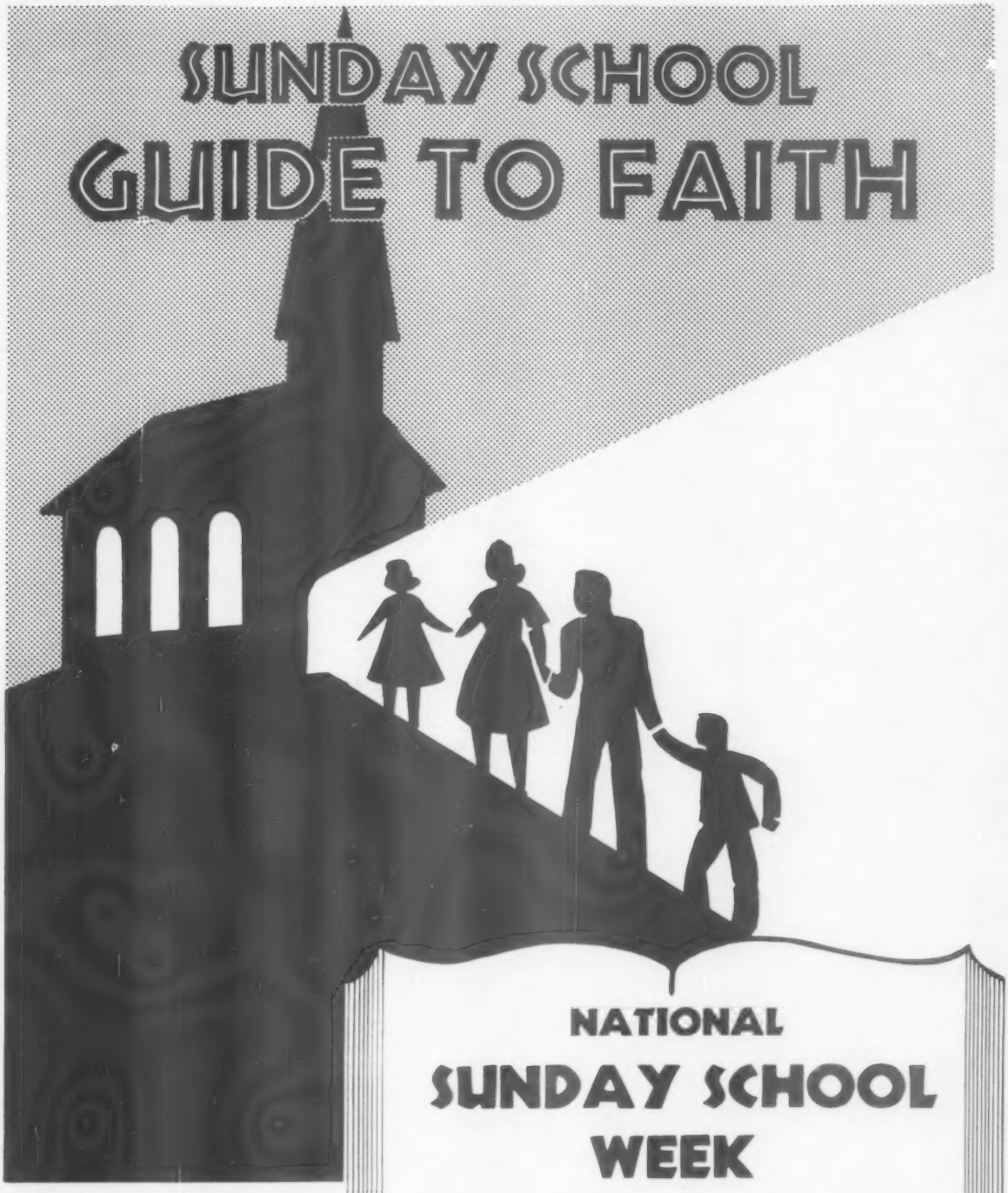

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New Products

New Tempil° Pellets

Tempil° Corp., 132 W. 22nd St., New York 11, N. Y., presented for the first time Tempil° Pellets to indicate temperatures of 2800, 2900 and 3000° F, at the Western Metal Exposition in Los Angeles—Pan-Pacific Auditorium, March 20th and 24th. This brings to 94 the number of specific temperature ratings of Tempil° Pellets available in systematically spaced intervals covering the full range from 100 to 3000° F.

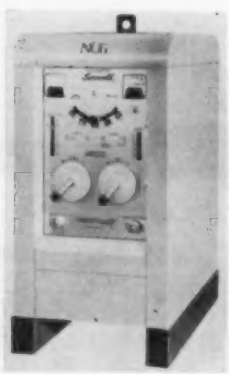
Current technological advances steadily increase operating temperatures which must be evaluated. The newly-developed Tempil° Pellets provide a convenient means of determining high-temperature levels with the accuracy of within 1% characteristic of all Tempil° temperature indicating products, according to the company.

For details, circle No. 101 on Reader Information Card.

Continuous Slope-Control Welding Unit

A new d-c welder with continuous voltage and slope adjustment, and which is especially adapted to high-speed welding on light-gage metal, is announced by National Cylinder Gas Div., Chemetron Corp., 840 N. Michigan Ave., Chicago 11, Ill.

The "Sureweld" DCRP-33 welder provides five specific voltage steps with continuous selection throughout the entire range, and offers indefinite continuous adjustments of the volt-ampere curves. The operator is able to make desired slope and voltage adjustments during the course of the weld.



The welder provides currents as low as 25 amp at 14 v and can weld alloys and other metals in the range of 0.030 in. without burn-through or spatter at relatively high speeds. Rated welding current is 300 amp at 100% duty cycle. A 115-v outlet is provided to accommodate input leads to automatic control equipment.

Optional water coolant systems with 10 and 40-gallon capacities, and running gear to carry the welder, water coolant system and two gas cylinders, are available.

For details, circle No. 102 on Reader Information Card.

Manganese-Nickel Steel Welding Electrode

Manganal Flo-Kote, the a-c, d-c, 11–13½% manganese-nickel steel welding electrode has all the ease of handling associated with mild or stainless steel electrodes; yet it is said to be a genuine manganese-nickel steel "solid state" electrode with all six vital alloying elements in the steel core, not in the flux coating, according to Stulz-Sickles Co., 929 Julia St., Elizabeth, N. J., its manufacturer. It reportedly produces tough, high strength weld deposits with full and uniform work-hardening and tensile properties; provides surfaces of remarkable resistance to erosion and shattering impact.

The company claims that Flo-Kote coating eliminates peening and bead-weaving; and that sound stringer beads can be run without porosity or cracking, and what's more, can be run out of position with the smaller diameters. No fancy, time-consuming welding techniques are necessary. A beginner can easily learn to make good welds with Flo-Kote in a short time, the company reports.

Manganal Flo-Kote electrodes are used not only in welding manganese steel to manganese steel, but also to produce what are claimed to be the strongest welds between manganese and mild or high-carbon steels. Furthermore, it is said that the welds can easily be cut with an ordinary acetylene torch when necessary.

For details, circle No. 103 on Reader Information Card.

Electrode for Out-of-Position Welding

A new welding electrode, designed for difficult out-of-position work in shipbuilding, pipe welding, construction, general maintenance and other applications where weld metal quality is critical, has been developed by the A. O. Smith Corp. 3533 N. 27th St., Milwaukee, Wis. A newly formulated coating is said to be responsible for the electrode's improved welding characteristics.

One result of the unusual formulation is a strengthened coating

crater. Added crater strength improves arc direction in horizontal and vertical working positions—especially where fit-up is tight—to facilitate single and multipass manipulation, according to the manufacturer.

The added strength also deepens electrode penetration, even in rough jobs, to produce welds that reportedly meet high-standard X-ray requirements. Fast-setting slag and good wetting action produce a uniformly flat bead, shown in field tests to be free of pitting, the company claims. The electrode is said to have the ability to produce vertical-down welds virtually free of pits.

The arc direction and penetration properties of A. O. Smith's new electrode—called the SW 610—also is reported to contribute to an increase in welding efficiency. Less weld metal is wasted because the operator puts it exactly where he

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wants it. The smooth, controlled arc transfers metal with less spatter, and reduces nonproductive clean-up time.

A member of the AMERICAN WELDING SOCIETY's E6010 class, the electrode is available in all sizes.

For details, circle No. 104 on Reader Information Card.

Combination Welding Machine-Power Supply

The Hobart Brothers Co., Troy, Ohio, GW-2235-S combination d-c welder and a-c power plant provides 200-amp dc, at 25-v, on 100% duty cycle for straight or reverse polarity welding. It has a welding

range of 30 to 325 amp for intermittent use.

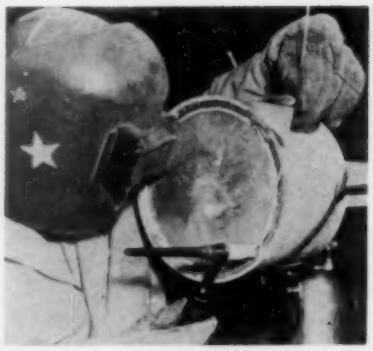
Power output is 2 kw at 110 v ac of auxiliary power when welding or a full 5 kw of 110/220 v ac when the unit works as a generating plant. A 14.2-hp, 2-cylinder, air-cooled Wisconsin gasoline engine powers the generator.

For details, circle No. 105 on Reader Information Card.

Tungsten-Arc Holder with 160 Amp Capacity

The highest amperage air-cooled tungsten-inert-gas holder was recently made available to industry by the Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y. The new H16-A Heliweld holder is reported to be the only air-cooled holder on the market with 160 amp a-c or d-c continuous capacity.

The H16-A is said to provide rapid, clean and smooth welding of thin gage aluminum, alloy and stainless steels, brass, copper, magnesium, molybdenum, nickel, silver and other metals. The new holder is easy to handle since its $2^{7}/_{8}$-in. head clearance permits its use in more confined spaces than any other



holder. Its air-cooled construction eliminates the need for a water system.

A variety of nozzle orifice sizes are available in $1^{1}/_{4}$- and $1^{5}/_{8}$-in. lengths. Made of alumina, these nozzles provide long life and good thermal and mechanical shock resistance. An added feature is the interchangeability of such accessories as collet cap assemblies, collets and nozzles with those in the H35-B, an Airco water-cooled holder rated at 350 amp dc.

Features of the new holder are minimum stub loss, efficient gas shielding and elimination of high frequency leakage. Tungsten electrodes from 0.020 through $^{5}/_{32}$ in. diam and from 2 to 7 in. in length can be accommodated. Argon, helium or mixtures of argon and helium shielding gases can be used.

For details, circle No. 106 on Reader Information Card.

Four-in-One Welding Torch

The Linde Co., 270 Park Ave., New York 17, N. Y., announced the new 500-amp ST-5 torch for all four types of gas-shielded metal-arc welding—spray arc, short arc, plug and spot welding. The versatile torch can be used with all "Sigmatic" welding machines, and features an in-line design—all service lines (gas, power, water and wire) enter the torch through the rear of the barrel. As a result, they can be supported on the welder's shoulder for balanced torch operation.

The ST-5 reportedly has a highly-efficient cooling system that brings water directly into the nozzle body to cool the contact tube, permitting continuous operation at currents as high as 500 amp, even with carbon-steel welding wire. The aluminum alloy pistol-grip handle is adjustable along the torch barrel, and is removable to permit using the torch in a mechanized installation. The large trigger is easily manipulated, even with heavy gloves, and a convenient wire-inching button is located at the base of the handle. Changing from one wire size to another is routine, since contact tubes are changed at the turn of a knob.

For details, circle No. 107 on Reader Information Card.

New D-C Welding Machines

The Lincoln Electric Co., Cleveland 17, Ohio, recently announced a complete line of new three-phase rectifier d-c arc welders for general use in production, structural and maintenance welding. The Idealarc R3M series, designed to NEMA industrial standards of 40

v, 60% duty cycle, incorporates highly efficient silicon rectifiers to produce d-c output in four sizes; 300, 400, 500 and 650.

Output characteristics of the new rectifier design have been specifically engineered to prevent electrode sticking on low current, small diameter electrode applications. At high amperage settings the unit maintains a smooth, quiet arc transfer. Wiring a push button magnetic-line contactor to strategically placed thermostats prevents thermal damage from overload, lack of ventilation, or single phasing. In addition to this thermal protection, all electrical parts are immersed after assembly in a corrosion

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Here is America's preferred Industrial X-ray Film in a new convenient form—in 200-foot rolls, and in three widths. Ready Pack rolls are the answer for panoramic or moving slit methods of radiography of thin-wall vessels and pipe, honeycomb, circumferential welds, etc. Unroll the needed film, cut it off, seal the ends with opaque, pressure-sensitive tape. You are ready to inspect aluminum or magnesium alloys, thin steels or anything where lead screens are not required.

Ready Pack rolls are supplied on cardboard cores, 12 inches in diameter. The film is enclosed in a light-tight wrap-around sealed covering, without interleaving paper. It keeps clean and does away with darkroom loading. For processing, just separate the wrap along the sealed edge and remove the film.

For further information or to order a supply, contact your x-ray dealer or write us for a Kodak Technical Representative to call.

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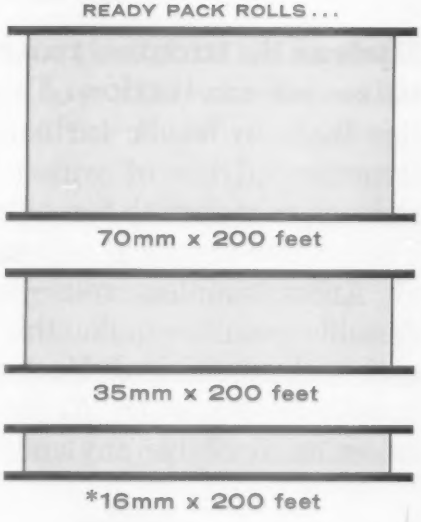

*For the present this size available only on a special order basis.

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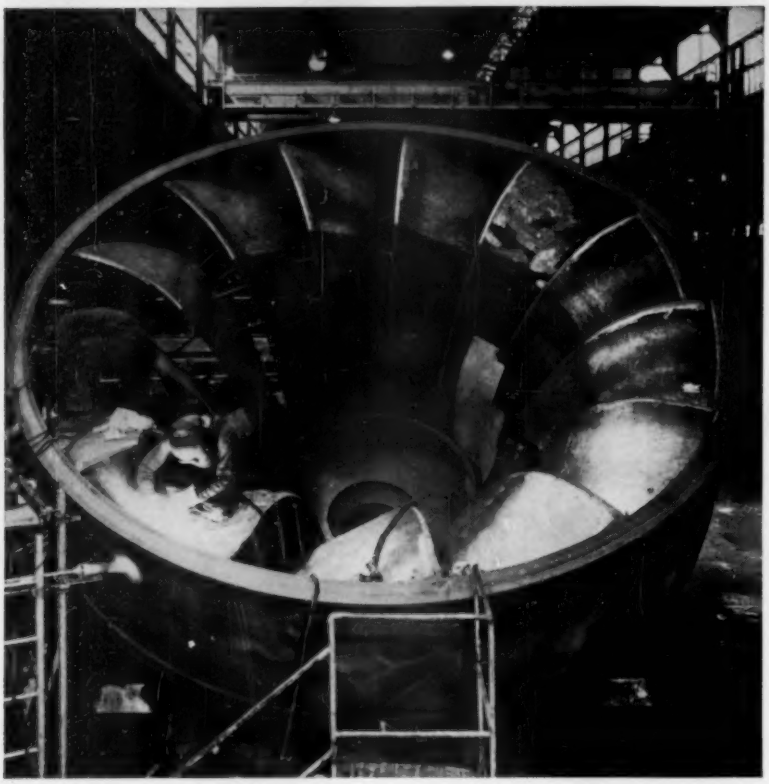
X-ray Sales Division, Rochester 4, N.Y.

Kodak TRADE MARK

For details, circle No. 35 on Reader Information Card

WELD WITH ARCOS STAINLESS ELECTRODES



Job Report Courtesy of Allis-Chalmers Mfg. Co., Milwaukee, Wisconsin

Hydraulic turbine runner blades overlaid to resist cavitation. To protect the blades of this huge hydraulic turbine runner from the destructive effects of water wear, Arcos stainless rods were selected for overlaying critical areas. The precise chemical and metallurgical properties of Arcos stainless rods—assuring uniform, predictable results—make this process both dependable and economical. Meet your stainless welding requirements with Arcos—the most complete selection available anywhere.

ARCOS

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For details, circle No. 56 on Reader Information Card

resistant insulating varnish and installed in a weatherized case.

Larger sized models can serve double duty as a power supply for semiautomatic submerged-arc welding and as a hand welder. Optional accessories include a three wheeled undercarriage for portable mounting, an ML-2 power pack, needed to transform the welder into an automatic welder power supply, and an accessory kit consisting of headshield, electrode holder, ground clamp and cables.

For details, circle No. 108 on Reader Information Card.

X-Ray Image Magnifier

The Picker X-Ray Corp., White Plains, N. Y., recently announced a new X-ray image amplifying technique that increases by five times the previous limits of effective fluoroscopic magnification and yields a clearer picture. According to the company, products previously too small to be tested by this means now can be examined with profitable results.

The Picker device reportedly permits fluoroscopic images of industrial products to be expanded effectively 20 times original size onto a television monitor or screen, compared with the four times previously possible. The Picker Image Amplifier also produces images more than 1000 times brighter than a standard fluoroscopic screen, it was stated.

The "Super Magnification" technique was achieved by means of a high-powered X-ray tube with a tiny, concentrated, focal spot. The angles of the X-ray striking the object being inspected are thus reduced and this yields increased image sharpness and magnification.

The new X-ray image amplifying technique can be likened to a flashlight (X-ray tube) with a concentrated, powerful beam sending light (X) rays over a greater distance after hitting the object to be seen (X-rayed). This contrasts with the previous principle similar to a flashlight with a wider, weaker beam sending rays over a shorter distance.

For details, circle No. 109 on Reader Information Card.

Magnetic-Particle Inspection System

The Instruments Div., Budd Co., P.O. Box 245, Phoenixville, Pa., recently announced that brazed metal structures, such as honeycomb, can now be nondestructively inspected by a system called recordaflux which permits quick and accurate determination of the in-

tegrity of a brazed joint.

This is a magnetic particle nondestructive inspection system. Unique feature is its film, containing fine magnetic particles, which sets up in a few minutes after application and "freezes" the magnetic particles in position. The particle pattern can be observed on the structure being inspected, then the film can be stripped off and kept as a permanent record.

With the system, careful selection of brazing alloys for a specific base metal reportedly makes it possible to determine the presence of brazed metal at a joint and also to ascertain whether the brazed metal has alloyed with the base metal. The system works on the basis that the magnetic particles detect changes from the unbrazed to the brazed state of the braze metal. These changes are said to be clearly shown by migration of the magnetic particles into easily-seen patterns which can be observed on the structure, then stripped off for a permanent record, if desired.

For details, circle No. 110 on Reader Information Card.

Heavy-Duty Soak Tank Cleaner

A new compound designed expressly for the removal of heavy and tenacious soils by immersion, has been introduced by Oakite Products, Inc., 19 Rector St., New York, N. Y.

The new material—Oakite HD 126—has a pH of 13.5 in the recommended solution concentration. Containing no rosin or soap, the compound is said to be completely rinsable. It is safe on steel, brass and magnesium; but is not recommended for use on aluminum and zinc. It is also said to have applications in barrel cleaning before plating operations, and for cleaning before vitreous enamel finishing. For most soak tank cleaning uses, recommended concentrations range from 4 to 12 oz per gal and temperature from 180 to 195° F. The concentration recommended for barrel cleaning and cleaning before vitreous enameling is 8 oz per gal at 180° F. The new cleaner is particularly recommended for use in hard water areas.

For details, circle No. 111 on Reader Information Card.

Nickel-Silver Brazing Alloy

Ambraze nickel-silver brazing alloy is available from American Brazing Alloys Corp., Pelham, N. Y., for use on steel, chrome molybdenum, manganese, stainless steel,

WELD WITH ARCOS FOR QUALITY WELD METAL

Arcos offers a complete line of filler metals for welding stainless, low alloy steels, mild steels, aluminum, and for hard surfacing . . . manually or automatically. Arcos covered electrodes, electrode wires, and filler rods are available for manual arc, submerged arc, inert gas, CO_2 shielded, and electroslag processes. The quality of all Arcos filler metal products, including fluxes for submerged arc welding and EB Inserts for root pass welding, is carefully controlled. *Make* sure it's Arcos . . . *be* sure of top performance.

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hi-speed steel, chrome nickel, vanadium steel, malleable iron, iron, nickel, monel and inconel.

The alloy is reportedly indispensable in the fabrication of small parts and in repairing milling cutters, slitting saws, broaches and all manner of machine tools made from tool steel. It is said to be unexcelled for bicycles, instrument parts, tubular steel furniture, light stainless steel assemblies and piping. In maintenance work, it is used for building up worn or broken teeth in gears or rebuilding worn trolley shoes.

This rod can be used in place of costly silver solders with attending higher strength when more heat is permissible. The working temperature of the alloy is 1700° F. It produces a corrosion resistant weld deposit with a hardness of 160–170 Brinell, a shear strength in excess of 150,000 psi and a tensile strength of 80,000 psi.

For details, circle No. 112 on Reader Information Card.

Industrial Line Voltage Compensators

Heavy-duty line voltage compensators capable of reducing ±10% line voltage fluctuations to ±1% are now in production by Glenn Pacific Corp., 703—37th Ave., Oakland, Calif.

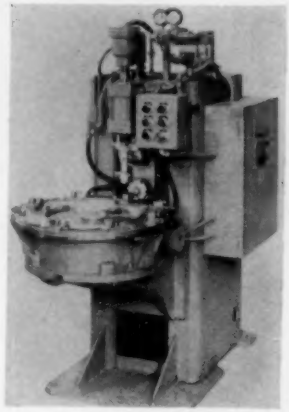
Available for all single- or three-phase line voltages to 600 vac, the compensators are self-contained convection-cooled units with 100% duty cycle ratings to 400 kva output per unit. They may be paralleled for higher capacities. Voltage regulation time response is adjustable; electronic sensing circuitry is available for applications requiring fast response with minimum output voltage fluctuation.

One unit is a 100 kva compensator installed at major radar facility, operating on 3-phase nominal 208 v input. It will accept line fluctuations of ±10%, and deliver 208 v ±1% at 300 amp with nondistorted sine wave at all settings.

For details, circle No. 113 on Reader Information Card.

Dial Indexing Welding Machine

A conventional dial indexing unit for manual loading of two small transistor case halves and ring projection welding and automatic ejecting is available from Acro Welder Manufacturing Co., 1719A W. St. Paul Ave., Milwaukee, Wis. Welding head is low inertia antifriction linear ball bearing diaphragm type with selective deflection firing. Indexing table is 8 station Geneva motion motor driven with electric clutch brake.



For details, circle No. 114 on Reader Information Card.

New A-C, D-C Welding Unit

A new "Sureweld" a-c, d-c gasoline-engine-driven welder for rugged construction, farm, maintenance and repair jobs in the field has been announced by National Cylinder Gas Div. of Chemetron Corp., 840 N. Michigan Ave., Chicago 11, Ill.

The Model SGAD-225-L produces 300 amp. at 30 v ac, or 225 amp at 30 v d-c welding current at 100% duty cycle. The unit is compact for easy movement on a trailer or hand running gear.

The welder functions efficiently for metallic inert-gas welding, and with a high-frequency conversion unit it becomes an excellent a-c welder for the tungsten inert gas welding process, the manufacturer claims. The unit produces 115/230-v single-phase 60 cycle a-c power for operating lighting systems and for emergency use, and can produce 115 v auxiliary d-c power while welding.

The welder is 53 in. long, 25 in. wide and 36 in. high. It is powered by a Kohler 24.4-hp engine with an electric starter.

For details, circle No. 115 on Reader Information Card.

Tubular Stainless Steel Composite Wires

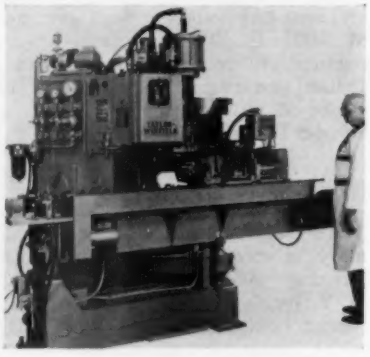
Stoody Co., Whittier, Calif., originator of tubular hard-facing and rebuilding wires for automatic and semiautomatic welding, is now producing tubular stainless steel composite wires. Close control of alloy content is made possible through use of the tubular fabricating method—a process proved by 14 years of use during which time many millions of pounds of hard-surfacing alloy wires have been produced. In addition, fabrication permits wide variations in analyses with no increase in production costs. AISI stainless steel compositions are obtained by regulating alloy mixture with a given quantity of steel strip. All Stoody Stainless Steel Wires conform to ASTM and AWS standards.

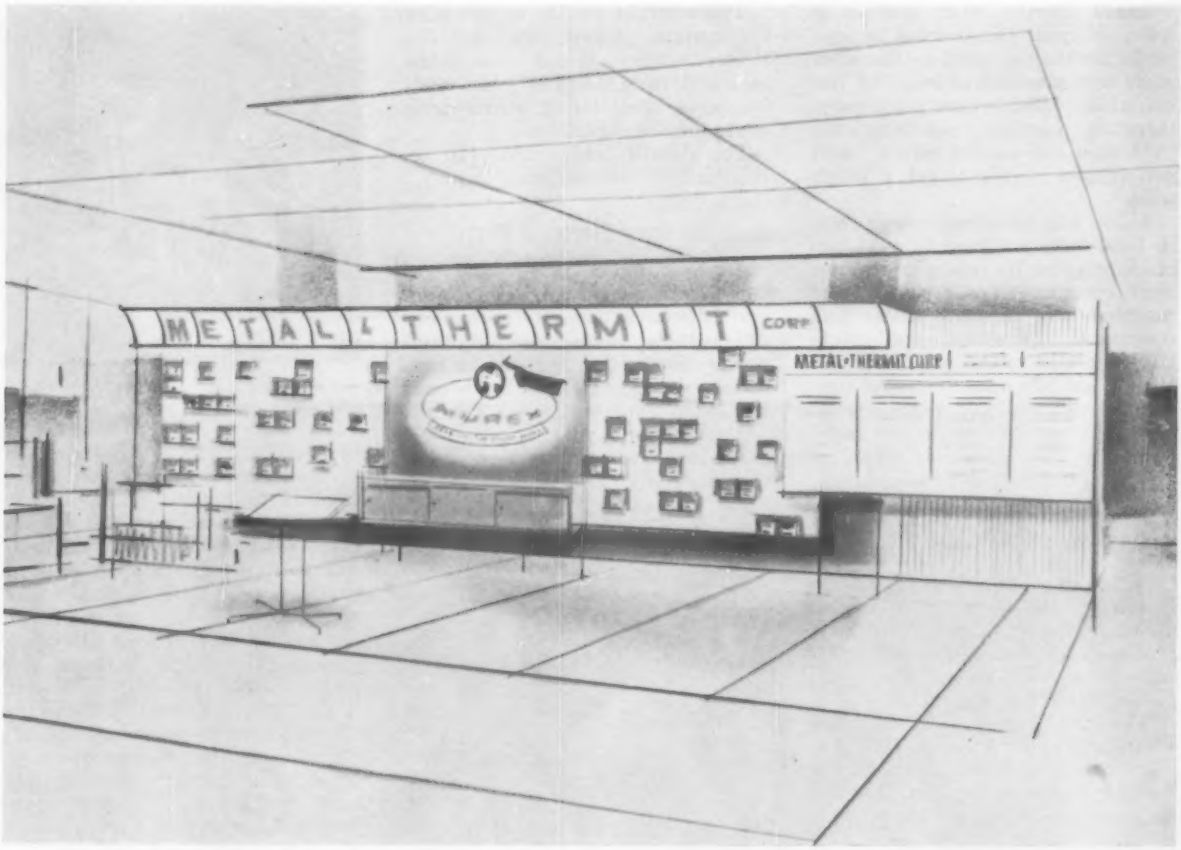
Designed for application by automatic and semiautomatic welding processes, Stoody stainless steel wires can be deposited by metal arc inert-gas, tungsten-arc inert-gas and submerged-arc processes. Available in $^{3}/_{32}$, $^{7}/_{64}$, $^{1}/_{8}$, $^{5}/_{32}$ and $^{3}/_{16}$ in. diam, Stoody stainless steel wires are supplied, depending upon wire size, in 25-lb spools, 25, 50 and 100-lb coils and in 200 and 500-lb Payoffpaks. Other sizes and weights can be supplied on special order.

For details, circle No. 116 on Reader Information Card.

Resistance Welding Machine for Studs

Resistance welding of 12 studs to each of two bars is done automatically in a dual-ram projection welding machine from the Taylor





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For details, circle No. 36 on Reader Information Card

Winfield Corp., 1048 Mahoning Ave., Warren, Ohio, using hopper feeder for the $^{3}/_{8}$- to 24-in. threaded studs and mechanical index of bar materials. Used in farm machinery, threshing machine "rub bars" are 1045 steel and welded with a "chill and temper" cycle to get a tough weld.

A 150 kva transformer and 6000 lb total force are used to weld two studs at once, by means of a series weld circuit. Once initiated, the machine goes through 12 welding operations (24 studs) and ejects the assemblies to the left. Operator then loads two more bars and continues. Production rate is 120 assemblies or 1440 welds per hour.

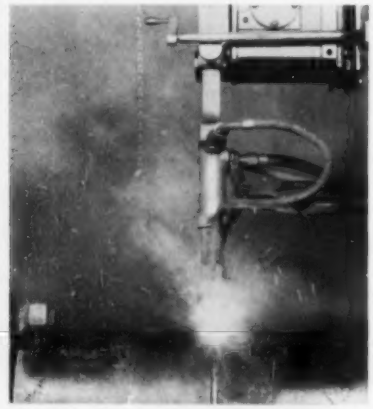
For details, circle No. 117 on Reader Information Card.

Automatic Roll Welding

A new process, which reportedly eliminates the need for a manual stringer bead or for a backing ring, has been developed for the fully-automatic roll welding of pipe by Hobart Bros. Co., Troy, Ohio.

The automatic submerged-arc welding process is successfully employed in shops for subassemblies and for double-ending line pipe, but it is necessary to use a backing ring—or weld the first pass with manual arc or tungsten-inert-gas process.

The new Hobart microwire weld-



ing system which employs carbon dioxide as the shielding gas, has successfully butt welded pipe, laying the stringer bead automatically without use of a backing ring.

The microwire automatic welding equipment includes a wire feeder coupled to a specially designed constant voltage motor generator welder. Filler wire is fed to a fixed welding torch for flat position or roll welding, or to a lightweight hand torch for semiautomatic applications.

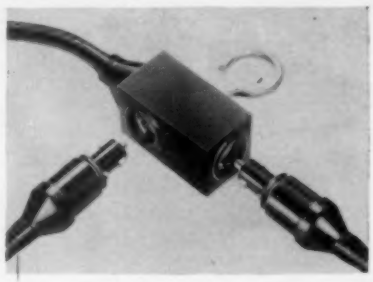
The water-cooled torch contains the current pickup tube and the electrode wire. It also directs the carbon dioxide shield into the welding zone, prohibiting atmospheric contamination of the weld.

For details, circle No. 118 on Reader Information Card.

Explosionproof Electrical Plugs

Explosionproof plugs and receptacles for safe, rapid connection and disconnection of permanent or portable electric lighting and power distribution systems in hazardous areas have been introduced by J. B. Nottingham & Co., Inc., 441 Lexington Ave., New York 17, N. Y.

Approved by the U. S. Navy for areas where Saran plastics work is



being done, the new "Industriline" plugs and receptacles may be used 2-, 3-, or 4-wire circuits rated as high as 240 v, 15 amp or 120 v, 30 amp. Plug and receptacle contacts of electrical-grade copper are solidly encased in neoprene bodies.

The possibility of a spark igniting an explosive atmosphere is prevented by plug and receptacle design. When a plug is inserted into a receptacle, a lip on the former snugly fits a collar on the latter to form a sealed chamber. Only after this chamber is closed can the plug be turned to engage plug and receptacle contacts and complete the circuit. The circuit is made or broken only while the contacts are enclosed in the sealed chamber.

For details circle No. 119 on Reader Information Card.

Atmospheric Heated Flowmeter Regulator

A new atmospherically heated flowmeter regulator for gas-shielded metal-arc welding using CO_2 gas has been marketed by Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y. This new regulator is said to eliminate the problem of freeze-up in flow control equipment and the need for cumbersome supplementary heat

sources.

The two-stage CO_2 solar-heated flowmeter regulator is equipped with an atmospheric heat pickup element to handle nearly all carbon dioxide shielding gas requirements in arc welding. The regulator will perform satisfactorily in most applications where the flow and duty cycles do not exceed 80 ft per hr. However, where the duty cycle is very high, a larger heat pickup element is used.

The unit consists of a chrome-plated pre-set single stage regulator, a heat exchange coil, a second stage of pressure reduction and a float type variable area pressure compensated flowmeter that indicates the flow in standard cubic feet per hour.

Freezing of the flow control equipment is avoided by isothermically expanding the high pressure CO_2 gas through two stages of pressure reduction.

Elimination of bulky external heating units provides for simplicity in operation. Pre-setting of the regulators is advantageous since no correction factor is required and reading accuracy is not affected by back pressure.

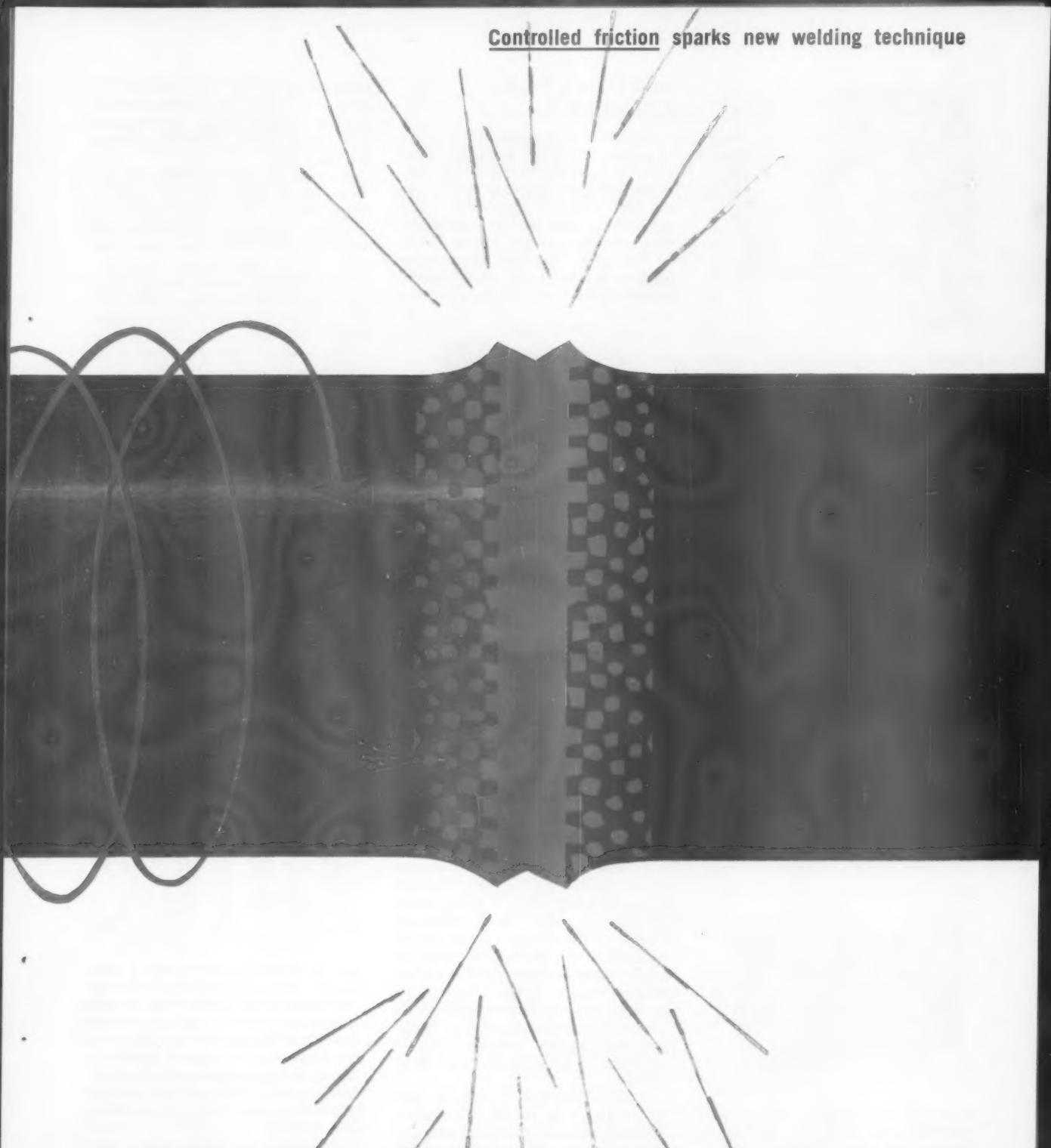
For details, circle No. 120 on Reader Information Card.

Welding Machine for Ball Joint Assemblies

A new 10-station rotary index automation machine that combines assembly, lubrication and CO_2-shielded arc welding operations to completely fabricate ball joint assemblies has been designed and built by Expert Welding Machine Co., 17144 Mt. Elliott Ave., Detroit 12, Mich. This automation concept reportedly permits a reduction in ball joint assembly costs because the complete part is fabricated on one machine.

The machine automatically is said to load a ball joint body, to apply a lubricant to the body in the

Controlled friction sparks new welding technique



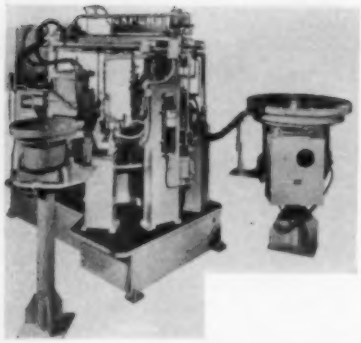
A newly developed **AMF FRICTION WELDER** fuses ferrous and nonferrous metals without flux or filler material by using only heat generated by friction. It works equally well for some nonmetals. / In joining alloy or carbon steels, for example, this union is accomplished in less than thirty seconds as the friction welder forces a revolving workpiece against a stationary piece at surface speeds in excess of 50 fps, pressures approaching 1,500 psi. The materials can be the same, steel to steel or aluminum to aluminum, or different, stainless steel to aluminum. Heat generated by friction between the mating surfaces produces the welding temperature which joins the materials. / This technique promises dramatic advantages for automating welding processes. It promises to provide better, faster welding production at lower cost and to permit economical welding of materials that up till now have been difficult or impossible to weld.

SEE AN ACTUAL DEMONSTRATION OF FRICTION WELDING AT THE A.W.S. WELDING SHOW, BOOTH 209. Detailed information on request. **AMERICAN MACHINE & FOUNDRY COMPANY**

AMF

For details, circle No. 37 on Reader Information Card

Research and Development Division — 689 Hope Street, Springdale, Connecticut



correct amount and in the proper area, and automatically to load a bushing component into the ball joint body. A stud and spring are manually loaded into the body. The machine then automatically press assemblies a cap into the body and automatically welds the component parts together to form a complete ball joint assembly. Production rate on this machine is 300 assemblies per hr at 80% efficiency.

The machine occupies a floor space of approximately 10 ft x 10 ft and is 7 ft high. The machine is totally air powered and electrically sequenced. Power for the cam drive is supplied by a 2-hp electric motor.

For details, circle No. 121 on Reader Information Card.

Electronic Governor for D-C Motors

The Linde Co., Div. of Union Carbide Corp., 270 Park Ave., New York 17, N. Y., has announced a new heavy-duty electronic governor for precise speed control of shunt wound d-c motors up to 1 hp. The governor maintains a constant motor

speed at any selected value despite variations in load, line voltage or motor temperature. Operating from a 230-v 50–60 cycle single phase line, the unit is available either as a stripped chassis suitable for incorporation into other equipment, as a rack mounted unit or as a self-contained unit enclosed in a cabinet.

Further information, may be obtained from the Electric Welding Dept. of Linde.

For details, circle No. 122 on Reader Information Card.

Single Phase A-C, D-C Welding Machine

The Miller Electric Mfg. Co., Appleton, Wis., has recently introduced a new a-c, d-c welding machine using single-phase service in 300, 400 and 500 amp sizes. The machine is said to have considerable versatility and a modest price.

The unit features continuous current control; an open circuit of 80 v in both ac and dc, plus two

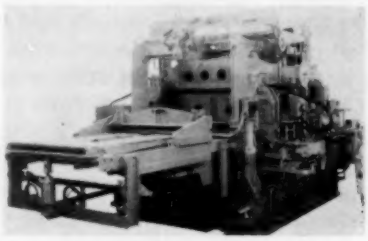
wide welding currents in each; and Miller's semiautomatic rectifier. Forced draft ventilation, dead front construction, and a sturdy drip-proof cabinet are additional advantages pointed out by the manufacturer.

For details, circle No. 123 on Reader Information Card.

Welding Heavy Strip

A new continuous welding machine made by Taylor Winfield Corp., Warren, Ohio, is designed to produce a sound weld, trimmed smooth to the strip thickness, which is suitable for further cold reduction in the same manner as the parent strip material. Large coils, built up by flash welding in steel mill pickle lines, will contain less off-gage material and higher tonnage can be achieved in later rolling and processing.

After flash-butt welding and trimming, this machine automatically notches or clips the edges of the strip at the weld to remove sharp



protrusions which are a hazard to following operations in high-speed process lines. These protrusions occur when joining strips of different widths.

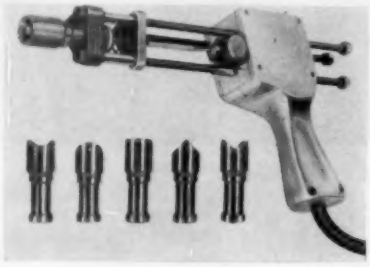
Various machine sizes handle strips to a maximum of 0.250 x 84-in. wide. The welder positions the ends of two strips, flash welds them together and traverses the joint to a draw-type, multiple-cutter trimmer which smooths the top and bottom surfaces. Machine then moves the joint into position where cutters engage both edges of the strip and clip any protrusions at the weld.

Hydraulic operation of the traversing clamp quickly moves the weld to trimming and edge clipping stations for rapid and automatic processing of the joint.

For details, circle No. 124 on Reader Information Card.

Electric Arc Gun

The Beeco Manufacturing Corp., P. O. Box 116 Cranford, N. J., recently announced the availability of a new patent-pending electric arc gun which serves as a spot welder, stud welder, tack welder, button welder, hole burner and riveter. When connected to any ac or dc welding machine power supply, the Beeco "Six Shooter"



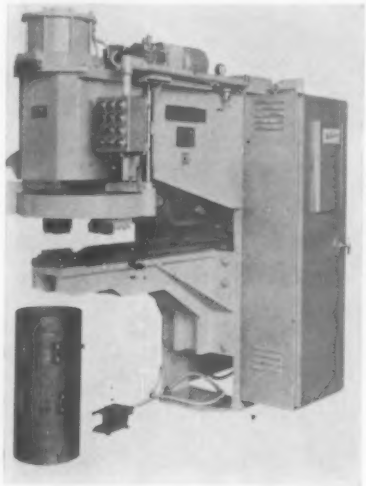
is said to burn a hole in two or more pieces of metal of any gage or combination of gages with a sum thickness up to $^1/_4$ in. on a single downward thrust of the gun. As hand pressure is released gradually and an exclusive spring-return mechanism moves the gun up, the rod melts filling the hole with a strong, sound weld.

Complete arc penetration may produce a hole, or a rivet as desired. A partial arc penetration may produce a stud, spot, tack or button weld as required. No back-up electrode or welder's helmet is needed to operate because of its exclusive design. When tested, the tensile strength of a $^3/_{32}$-in. rod spot weld was reportedly 1450 lb.

For details, circle No. 125 on Reader Information Card.

Press-Type Projection Welding Machine

The Federal Machine and Welder Co., Warren, Ohio, has announced the availability of a federal press-type projection welding machine equipped with a special four-station dial-type upper die holder. This unique arrangement, valving,



regulating and piping allows selecting four different weld forces through a four button push button station. The four push buttons reportedly permit the operator to choose any one of the four stations by simply pressing its button. The special four-station dial-type upper head is said to automatically move the die selected to the weld station. The proper air pressure for this particular station will also be selected automatically as well as the particular heat setting on the control panel.

This machine has a throat depth of 48 in. from the centerline of the slide to the front face of the frame and the lower arm is made of fabricated steel with a cast copper conductor. This arm is designed to accommodate several different diameters and lengths of tanks and still maintain maximum strength with minimum deflection. The machine is powered with a 500 kva water cooled welding transformer arranged with 16 steps of heat regulation. It is capable of providing a maximum secondary short circuit amperage of 100,000 amp.

The machine has an antifriction roller bearing slide operated by a 12-in. diam air cylinder developing a maximum weld force of approximately 9000 lb at 80 psi air line pressure.

For details, circle No. 126 on Reader Information Card.

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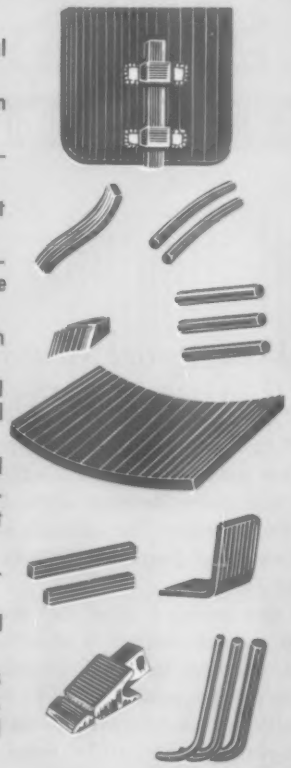
BUCKET DOOR LATCH PIN BRACKETS — form from Manganal Flat Bars.
BUCKET SIDES — cut from Manganal Flat Bars.
BUCKET CUTTING EDGE FOR WORN LIP — bend from Manganal Hot Rolled Wedge Bar.
BUCKET TOOTH SOCKETS—reinforce with Manganal Round Bars.
BUCKET CUTTING EDGES BETWEEN TEETH — cut from Manganal Hot Rolled Wedge Bars.
BUCKET FLOOR LINER — flame cut and bend from Manganal Hot Rolled Plate.
BUCKET HITCH PINS & HINGE PINS — cut from Manganal Round Bars.
CRACKED BUCKET LIP—repair with Manganal Electrodes for extra strength.
BUCKET HEEL — reinforce with Manganal Flat Bars.
BUCKET TAPERED LIP—form from various thicknesses of Manganal Round Bars.
BUCKET TEETH — repoint with Manganal Wedge Bars.



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...*Bridgeport Brass Uses EASY-FLO 45 to Bond Their Clad Metals*

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SUPPLEMENT TO THE WELDING JOURNAL, APRIL 1961

The Role of Hydrogen in Arc Welding with Coated Electrodes

Paper sponsored by IIW analyzes sources and subsequent effects of hydrogen in covered-electrode welding

BY N. CHRISTENSEN

Introduction

It is not the intention of the present survey to deal with all aspects of hydrogen in metal-arc welding. This would indeed amount to a major task. It may be appropriate, at this joint meeting of the AWS and the IIW, to restrict the discussion mainly to those sides of the subject with which the Subcommission A ("Hydrogen in Weld Metal") of the IIW Arc Welding Commission has been concerned. However, it will not be practical to keep strictly to this limitation, nor will it be possible to mention all contributions made within the IIW. Needless to say, any statement made without special reference will reflect the opinion of the author and might not necessarily be shared by the IIW.

Briefly, the following topics are discussed in the order given:

1. Sources of hydrogen in metal-arc welding.
2. Assessment of hydrogen in mild and low-alloy-steel weld metal.
3. Effects of hydrogen on the service properties of the weldment.
4. The role of hydrogen in acceptance testing of electrodes.

N. CHRISTENSEN is chairman of the IIW Subcommission A (Hydrogen in Weld Metal) of Commission II (Arc Welding); he is with the Engineering Research Foundation at the Norwegian Institute of Technology (SINTEF), Trondheim, Norway.

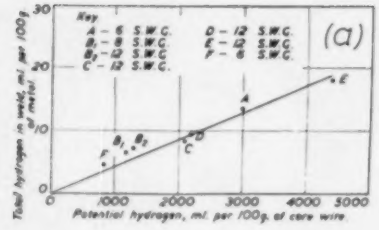
Paper to be presented at AWS 42nd Annual Meeting in New York, N. Y., Apr. 17–21, 1961.

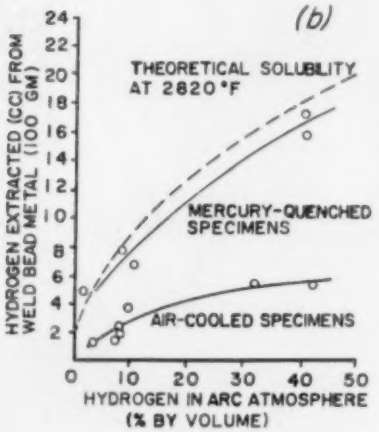
Sources of Hydrogen in Metal-arc Welding

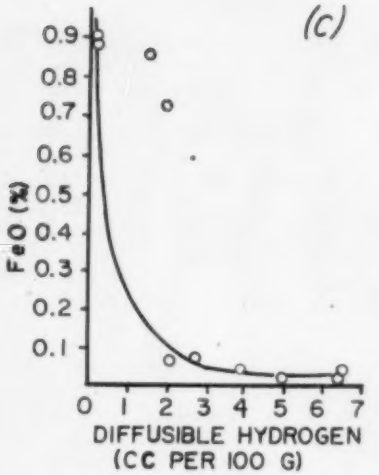
It has been known for a long time that the electrode coating represents the most important source of hydrogen in nearly all practical cases. An illustration of the effect of hydrogen in the electrode coating has been reproduced in Fig. 1a from an investigation by Sloman, Rooney, and Schofield.[1] The potential hydrogen of the electrodes was determined by combustion of the coating in a stream of oxygen, and the hydrogen content of the weld metal was measured by means of the vacuum-fusion method. Although the hydrogen content in the weld metal may also depend on a number of factors not shown in Fig. 1a, the importance of the potential hydrogen content is clearly demonstrated.

Mallett and Rieppel,[2] in their study of under-bead cracking, were able to establish correlations between the composition of the arc atmosphere and the hydrogen content of the weld metal. Figure 1b from their paper confirms nicely the square-root relationship predicted from Sievert's law. Furthermore, the two curves in Fig. 1b obtained after quenching and air cooling, respectively, may serve as an illustration of the experimental difficulties encountered in this field. Clearly, a comparison of results might be quite misleading if one set of data were obtained with air-cooled samples and another set with quenched ones.

Mallett and Rieppel[2] and Mallett[3] concluded that a high-temperature chemical equilibrium is established in the arc plasma. This implies a rapid interaction of the gaseous constituents. As a consequence, it is of little importance whether hydrogen was originally present in the coating as an organic component or, for instance, as hydroxyl groups. The chemical state of hydrogen in the coating is important only insofar as the carrier of hydrogen may in some cases be lost by volatilization before it can be introduced into the arc. A further consequence of chemical equilibrium has been pointed out by van den Blink.[4] Addition of water vapor to the arc atmosphere may or may not result in an increased hydrogen content of the weld metal, depending on conditions controlled by the water-gas equilibrium. In the arc atmosphere of cellulosic and rutile-cellulosic electrodes, such additions will mainly have the effect of a diluent, thereby reducing the partial pressure of hydrogen. Water, on the other hand, will be nearly completely converted to hydrogen in the carbon monoxide atmosphere of lime-fluorspar electrodes. The




(b)
THEORETICAL SOLUBILITY AT 2820 °F
MERCURY-QUENCHED SPECIMENS
AIR-COOLED SPECIMENS
HYDROGEN EXTRACTED (CC) FROM WELD BEAD METAL (100 GM)
HYDROGEN IN ARC ATMOSPHERE (% BY VOLUME)



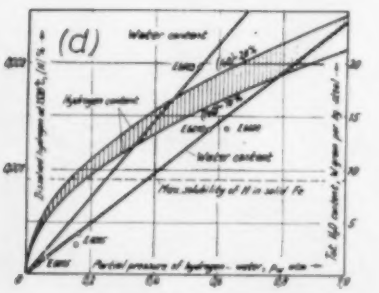


Fig. 1—Examples of weld metal hydrogen content in relation to potential hydrogen content and to chemical factors (a—Sloman, Rooney, and Schofield;[1] b—Mallett and Rieppel;[2] c—Reeve;[5] d—Christensen[6])

amount of potential hydrogen is, therefore, not the only factor of importance; it will also be necessary to know which fraction of the potential hydrogen can be transferred to the bath.

The dissolution of hydrogen in the weld pool has been studied by Reeve[5] who used the oxygen content of the weld metal as a criterion of its ability to absorb hydrogen. Some of his results are shown in Fig. 1c, where the content of "FeO" in the weld metal has been plotted against "diffusible" hydrogen content. The former figures have been measured by fractional vacuum-fusion, the latter ones by extraction at 250° C. The significance of the term "diffusible hydrogen" is discussed later; at the present stage it is sufficient to point out that an oxidized (dead-soft) weld is relatively insensitive to hydrogen. This conclusion is in accordance with practical experience.

Finally, since the deoxidation of the weld metal is closely connected with the iron oxide content of the welding slag, the conditions of hydrogen pickup can also be stated in terms of a simultaneous equilibrium between the arc atmosphere, the liquid metal and the liquid slag. In Fig. 1d this principle has been used in an attempt to estimate the hydrogen content of the weld metal from data that are readily measured.[6] An an example, an E6020 type of electrode containing a total amount of potential hydrogen—equivalent to, say, 15 g H_2O per kg core wire—is likely to give a combined partial pressure of hydrogen and water a little more than 0.6 atmospheres. Since the iron oxide content of E6020 electrode slags is generally in the range from 10 to 15%, a hydrogen content of about 18 ppm would be expected in the weld metal from this electrode.

In summing up information presented above on the sources of hydrogen, it should be emphasized that these examples must not be generalized uncritically—the straight-line relationship of Fig. 1a might be curved under other conditions, and the concept of chemical equilibrium, though useful in the case of deoxidation, might be misleading under other circumstances. It may be necessary to proceed with due caution even in those cases when measured hydrogen contents have been reported as will be seen from the discussion on the determination of hydrogen.

Assessment of Hydrogen in Mild and Low-alloy-steel Weld Metal

As shown in Fig. 1b, the method of sampling may affect the result of hydrogen determination. Evidently, the quenched-sample data are more truly representative of the hydrogen content of the liquid metal, while data from the air-cooled samples might be more useful in an investigation of hydrogen retained under practical conditions of welding. Furthermore, it is well known that the result of analysis of a given sample will depend on the analytical procedure.

As a consequence, it must be accepted that no single method of sampling and analysis can be devised to meet all requirements. It would indeed be useful if it were possible to establish correlations between hydrogen contents obtained by means of the various procedures, in terms of the thermal history of the sample, of sample location and of the method used in the deposition of the metal analyzed. An attempt is made in the following sections to discuss these factors together with the analytical procedures.

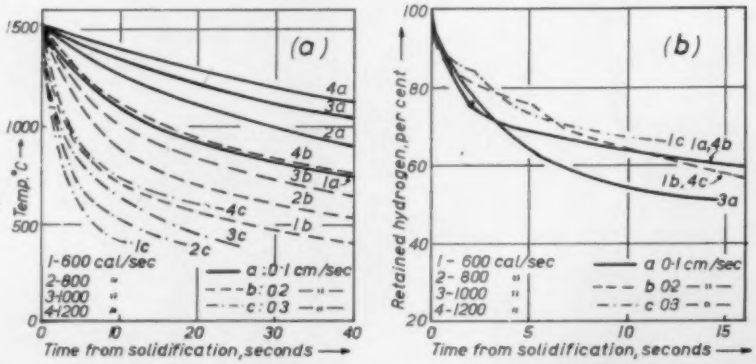


Fig. 2—Single beads deposited on a 1-cm plate[7] (a—estimated cooling rates; b—estimated losses of hydrogen)

Losses of Hydrogen Prior to Sampling

A rough estimate of diffusional losses may be made through a combination of hydrogen diffusivities, as a function of temperature, and the cooling program of the weld metal. Details of calculation will be reported elsewhere.[7] For purposes of illustration it is sufficient to state the assumptions involved. A point-source equation, modified for a finite plate thickness, according to Rykalin,[8] has been used for computation of the temperatures at the center-line of a single bead. Taking the diffusivities of hydrogen in pure iron published by Geller and Tak-Ho-Sun[9] and replacing the bead by a long prism of equivalent dimensions, the fractional losses may be estimated if the initial concentration immediately after solidification is assumed to be uniform.

The conditions of welding and the calculated temperatures will be seen from Fig. 2a. Two curves corresponding to normal welding and two curves representing extreme conditions, have been transformed into curves of retained hydrogen as shown in Fig. 2b. It will be noted that the estimated losses of hydrogen during the first 5 or 10 sec after solidification are nearly identical in spite of the widely different cooling rates indicated in Fig. 2a. Accordingly, the conditions of welding need not be specified rigorously when it is intended to measure the initial hydrogen content. Furthermore, it is seen that the initial content cannot be assessed except by extrapolation. The correction to be added will depend on the time of sampling.

Nonuniform Distribution of Hydrogen

If the estimated losses of hydrogen are replotted in terms of distance from the rear boundary of the end crater, steeper gradients will be obtained at low speeds of welding. At a given position of sampling, a smaller correction will, therefore, be needed in cases of rapid welding. This effect has been illustrated in Fig. 3a for welding conditions 1c and 2b. At a sampling distance between 10 and 20 mm the calculated differences between initial concentration C_o and actual concentration C will be about 35 and 45% respectively. Preliminary data, obtained with acid type weld metal under these conditions of welding, scatter within bands calculated from initial concentrations of 25.1 and 26.9 ml/100 g in the former case and of 31.7 and 34.2 in the latter. While present experimental material is too meager for any conclusive statement, it appears that the estimated losses are of the correct order or magnitude.

The calculations and measurements discussed thus far refer to the hydrogen content of the weld metal proper. As known, it is common practice to include adjacent parts of the parent-plate material in the sample, as prescribed in the ASTM and the IIW methods to be discussed shortly. In this case, a fraction of the initial content will be recovered in the subsequent analysis, and the longitudinal gradient will be less steep. To the order of magnitude, one-half the correction indicated in Fig. 3a would be expected for conversion of measured values to the initial content. An example of measured longitudinal distribution is shown in Fig. 3b. The abnormally steep rise of the curves in the region of the end crater, itself, is probably an effect of arc blowing, which has been discussed elsewhere[10] and need not be considered here. At some distance from the crater, however, the concentration gradient is seen to be smaller than in the case of pure weld metal samples. The measured values are thus closer to the true initial content.

The *lateral* distribution of hydrogen is not so easily estimated. Experimental distribution curves, measured at half-length of beads of about 100 mm total length, are shown in Fig. 4. The peak values of hydrogen concentration, found at or close to the center of the

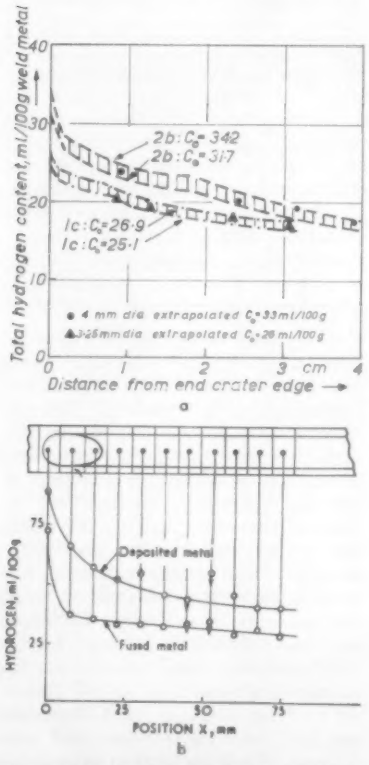

Total hydrogen content, ml/100g weld metal
2b: C_o = 34·2
2b: C_o = 31·7
1c: C_o = 26·9
1c: C_o = 25·1
● 4 mm dia. extrapolated C_o = 33 ml/100g
▲ 3·25 mm dia. extrapolated C_o = 26 ml/100g
Distance from end crater edge
a
HYDROGEN, ml/100g
Deposited metal
Fused metal
POSITION X, mm
b

Fig. 3—Longitudinal gradients in single beads (a—samples of pure weld metal;[7] b—samples including parent-plate material[10])

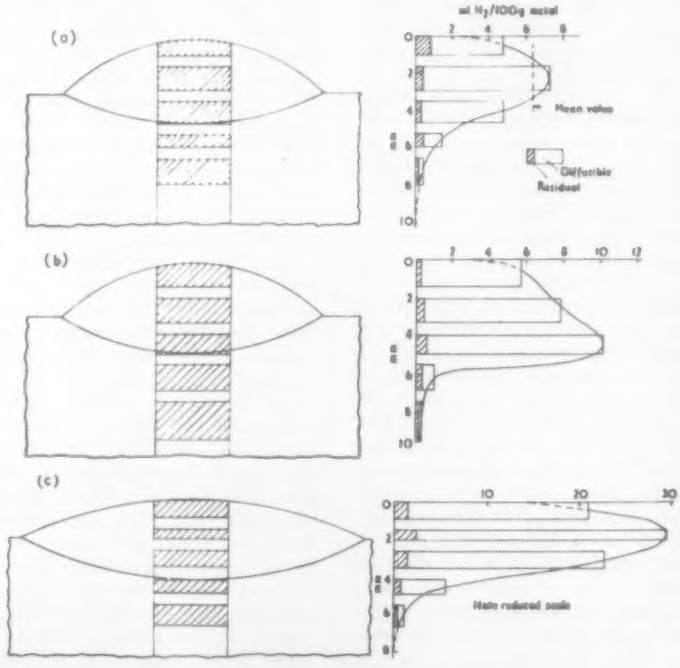


Fig. 4—Lateral distribution of hydrogen in single beads[10] (a—electrode B6, 4 mm diam; b—electrode B1X, 5 mm diam; c—electrode A1, 4 mm diam)

bead, are roughly twice the concentration close to the top surface. Further, it is confirmed that a significant fraction has diffused into the heat-affected zone.

Since the presence of hydrogen outside the weld nugget is a result of high-temperature diffusion which, in turn, is inherently connected with the process of welding, it is justified to include the surroundings of the bead in the sample for the assessment of the *initial* hydrogen content. For purposes of comparison of electrodes, the measured gas volumes may be reported on the basis of 100 g of deposited or fused metal (obtained, in the latter case, from cross-section measurements).

Hydrogen in Multilayer Deposits

Two factors should be considered when applying data of initial hydrogen contents from single-bead tests to a multilayer weld. First, losses of hydrogen may be expected during reheating of the weldment each time a new layer is being deposited; secondly, a trend in the opposite direction arises from deposition on a material containing more hydrogen than any wrought steel.

An experimental approach to this problem has been made by Roux,[11] who studied weld metal from rutile* and basic† types of electrodes when deposited on a strip of mild steel in the bottom of a copper mold. Hydrogen was extracted from the entire weldment at room temperature followed by hot extraction at 650° C. As an illustration, some of his results obtained with rutile electrodes have been replotted in Fig. 5. It will be seen that the ratio of measured gas volumes to *fused-metal* weights remains essentially constant, regardless of the number of passes. In the present case this ratio corresponds to a hydrogen content of about 13 ml per 100 g. When the same gas volumes are referred to the weight of *deposited* metal, the specific gas content is found to vary in the range from 40 ml per 100 g, for 6 g of deposited metal, to 16 ml per 100 g for a deposit of 113 g. The two methods of reporting the specific gas content would, of course, give identical results at a sufficient number of passes, when the sample would consist essentially of weld metal only.

In practical welding there is no water quenching between passes,

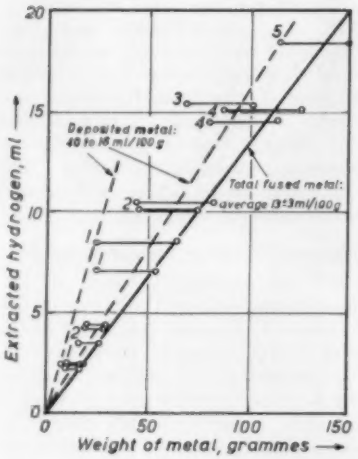


Fig. 5—Hydrogen in multilayer welds, replotted from data by Roux[11] (Numbers in the diagram denote number of passes)

and the chilling effect of the copper mold is absent. Further, a comparatively small amount of weld metal is usually surrounded by a much larger mass of parent-plate material, in contrast to the experiments described above, where the entire weldment or a substantial part of it was fused. In spite of these differences, it is probable that the average hydrogen content per unit mass of weld metal will not vary much from layer to layer even under normal conditions of welding. The absolute level of the hydrogen content will depend on the cooling program; as an indication, Blake[12] has reported that water-quenched single beads made with basic electrodes contain roughly 1½ times the amount found in the same weld metal when deposited in five layers with water quenching after the final run only.

No direct comparison has been made between hydrogen contents obtained with the arrangement of Roux and those measured in single-bead-on-plate tests like that recommended by the IIW.[13] However, since the cooling rates are high and the times to quenching are about equal in these two procedures, it is probable that the results will be nearly identical. Consequently, it is seen that the single-bead data will give more general information when evaluated in terms of fused metal. As a tentative conclusion, single-bead test data reported on the basis of fused metal may be considered representative of the highest hydrogen content to be expected in multilayer deposits from the same electrode.

Methods of Analytical Determination

Based on experience with cast and wrought steel, the total hydrogen content of a sample can be divided into two rather loosely defined groups: the "diffusible" fraction, which will be released on prolonged storing at or close to room temperature, and the "residual" fraction, which can only be recovered at elevated temperatures. A third smaller fraction, which might be termed the "fixed" fraction according to a suggestion by Cottrell[14] will not be released until the sample has been fused.

This subdivision into groups may be quite useful in many cases. An examination of the literature indicates, however, that there appears to be no sharp line of division between these groups. Thus, when the evolution of gas from a sample at room temperature has practically come to an end, further amounts will in general be released by increasing the temperature slightly. When degassing at this higher temperature has ceased, an additional amount can usually be extracted at a still higher temperature, and so on. The data in Table 1, reported for B.S. Class 2* weld metal by Blake,[15] indicate that the situation is quite similar in the case of weld metal.

Table 1—Effect of Temperature on Hydrogen Extraction from Weld Metal

Temperature, °C	Extracted gas in 24 hr, ml/100 g	Total gas, %
20	4.30	38.5
200	3.96	35.6
450	0.60	5.4
650	2.27	20.4
Sum	11.13	100.0

A transfer of hydrogen from the "diffusible" to the "residual" group has been observed by Araki and Ichihara[16] as a result of delayed quenching prior to the determination. Finally, since all processes controlled by diffusion will depend on the geometry, it may be expected that the analytical result will be affected by the size of the sample. For purely practical reasons it appears advisable to *define* the amount of diffusible hydrogen as that obtained in the former AWS-ASTM test[17]—that is, the amount extracted at 45° C during 48 hr from a single bead deposited on mild steel under specified conditions. Cold extraction data measured under other conditions will

* Corresponding to AWS Types EXX12 or EXX13.

† Corresponding to AWS Types EXX15 or EXX16.

* Electrodes of rutile type, corresponding to AWS-ASTM designation EXX12.

be referred to below in quotation marks.

The *residual* hydrogen content may be defined as the amount extracted at 650° C from samples previously degassed at a temperature not exceeding 45° C, regardless of the procedure of low-temperature extraction. The choice of 650° C is in accordance with well established steelworks practice, and an increased temperature of extraction will usually not affect the result materially until the temperature is raised above 1200° C.

The *total* hydrogen content has been defined by the IIW for practical purposes as the sum of the "diffusible" and residual contents, as measured on single-bead samples according to a recommended procedure.[13] Since "fixed" hydrogen has not been included in the IIW definition, the term "absolute content" is tentatively suggested when the vacuum-fusion method has been employed in the determination.

It may seem strange to define arbitrarily diffusible hydrogen in terms of a method which has been left out of the more recent AWS-ASTM rules of testing. This method has been examined in Subcommission A of Commission II. It is admitted that a great deal of scattering has been experienced, and the prescribed period of degassing appears to be too short. Nevertheless, this method appears to be the only one that has been used on a larger scale for this kind of measurement, and it has been considered useful to retain this procedure within the IIW for purposes of reference.

The recommended IIW procedure for the determination of total hydrogen contents has been referred to above on several occasions. The test piece assembly is shown in Fig. 6. Details of the procedure are given elsewhere.[13] Briefly stated, the weldment is quenched in water and subsequently in alcohol/solid CO_2; the total hydrogen content is obtained by addition of the volumes determined by cold and hot extraction.

The merits of this method may be briefly summarized as follows in light of the preceding discussion of sources of error:

1. The recommended procedure appears to be well suited for purposes of a relative grading of electrodes.

2. The true initial content immediately after crystallization is not obtained unless a correction is applied. To the order of magnitude this correction amounts to about 15%.

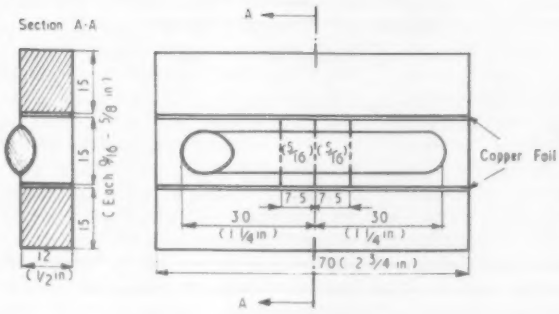


Fig. 6—Recommended test piece assembly for the assessment of total hydrogen contents[13]

3. A further correction is needed if the absolute content (including "fixed" hydrogen) is wanted; alternatively, the extraction at 650° C may be replaced by a vacuum-fusion determination.

4. It is not accurately known whether hydrogen contents reported on the basis of fused metal will be strictly applicable to multi-run welds prepared under the same conditions of rapid cooling.

5. For application to multilayer welds prepared under conditions of free cooling, any correction applied by calculation or, alternatively, by free cooling of the test-piece assembly will, at best, be approximately correct only.

It will be realized that neither the ASTM method for diffusible hydrogen nor the IIW procedure for total hydrogen contents will be adequate for all purposes, and it should be emphasized that both methods will give conventional figures. Despite their limitations it is hoped that they will be included in future investigations, whenever possible, so as to facilitate a comparison of results.

Effects of Hydrogen upon Service Properties

It has been found convenient to classify the harmful effects of hydrogen in two main groups: temporary deterioration of mechanical properties and permanent defects. By definition, the former of these groups will be associated with the "diffusible" fraction of hydrogen, since this fraction will eventually be released by natural aging. Permanent defects like weld metal fissures, under-bead and toe cracks, and weld metal porosity are frequently correlated with the total hydrogen content, but the "diffusible" fraction may play an important role even in these cases.

Hydrogen Brittleness and the Formation of Fish Eyes

Based on experience with wrought and cast steel, a temporary loss of ductility of weld metal is observed in static testing. There are in-

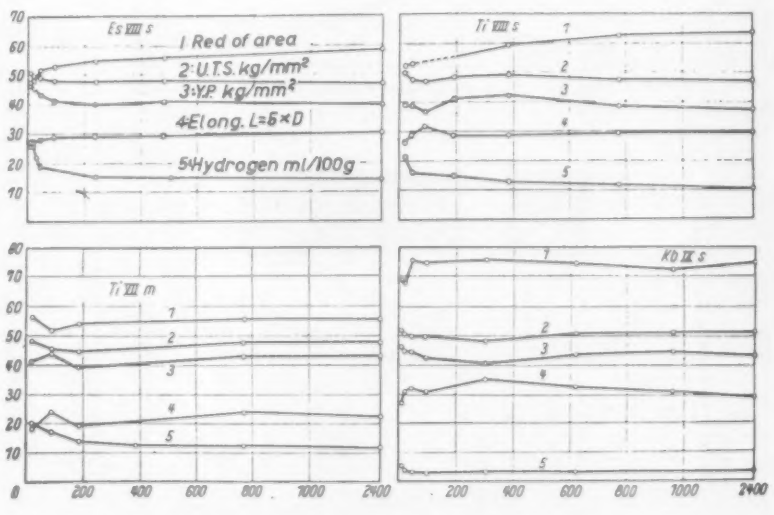


Fig. 7—Examples of recovery of tensile properties. After Hummitzsch[21]—nearest AWS equivalents to DIN 1913 designations: Es VIIIs–E6020; Ti VII m–E6012; Ti VIIIs–E6013; Kb IX s–E7016

Table 2—Reduction in Fish Eyes and Hydrogen with Prolonged Storage

Time, hr	4	24	96	2400	3600	5100
No. of fish eyes	3	4	2	1	0	0
Fish eyes in fracture, %	0.26	0.34	0.53	0.16	0	0
Hydrogen content ml/100 g of weld metal						
Fusion	30.0	25.8	18.0	12.3	...	8.1
1000° C	...	22.9	...	9.2	...	6.8
650° C	20.2	...	12.0	...	6.3	6.0
45° C	12.0	6.0	2.0	...	...	...

Table 3—Variation in Hydrogen Content by Type of Electrode

Diffusible hydrogen, ml/100 g (ASTM)	Electrode: ISO code	Electrode: Nearest AWS equivalent	Residual hydrogen content (650° C), ml H_2/100 g weld metal, after: 50 h	100 h	200 h	300 h	500 h	1000 h	16h at 250° C
30	E 432 R22	E 7012	9.5[a]	...	5.6/7.3[a]	6.6[a]	7.3[a]	8.2	10.9
23	E 332 T22	E 6013	22.5[a]	...	19.6/27.2[a]	...	...	...	...
41	E 423 C16	E 7011	11.9	13.8/12.5[a]	...	9.4/12.0	9.9/13.4[a]	...	4.5
22	E 243 A24	E 6020/-6030	6.4/6.9	3.8	...	4.1	...	...	...
6	E 355 B29	E 6015	2.0/2.6[a]	...	...	...	...	...	...

[a] Sample in which fish eyes were found.

dications of an effect of hydrogen upon the impact properties at room temperature[18] and on the transition range in impact testing;[19] however, from a practical point of view these effects are probably of less importance.

A typical example of weld metal tensile properties at various stages of natural degassing is shown in Fig. 7 taken from an investigation reported to the IIW by Hummitzsch.[20] Plates of 22 mm thickness were butt welded, and all-weld-metal tensile bars were machined and tested at intervals as shown. Samples for determining the absolute hydrogen content were tested by the vacuum-fusion method. It will be seen that there is a general trend of lowering of the hydrogen content with increased time of storing, of lowering of the tensile strength and yield point, and of a corresponding improvement of the ductility.

It is not easy to state when the process of recovery has been completed. The main period of degassing appears to be ended after a few weeks, but an improvement of ductility can be noted in some cases during later stages. Additional information may be obtained by examining the fracture surface, when the absence of fish eyes may be taken as an indication of complete recovery. It turns out that fish eyes may be found even after 2400 hr with the present geometry of weldment. The data in Table 2, obtained in continued testing of the acid electrode, indicate a further reduction of the hydrogen content and a complete absence of fish eyes after still longer periods of storing.

Fish eyes can be avoided through a short-time heat treatment prior to testing. The method agreed upon within the IIW consists in soaking at 250° C for 16 hr.[21] A comparison of tensile test data, after artificial degassing according to this procedure and after natural aging up to 1000 hr, has been reported to the IIW by Pfeiffer.[22] No fish eyes were found in the specimens that had been heat treated, and the ductility was roughly equal to that obtained after a sufficient period of natural aging. Pfeiffer's measurements also indicate that the residual hydrogen content, below which fish eyes do

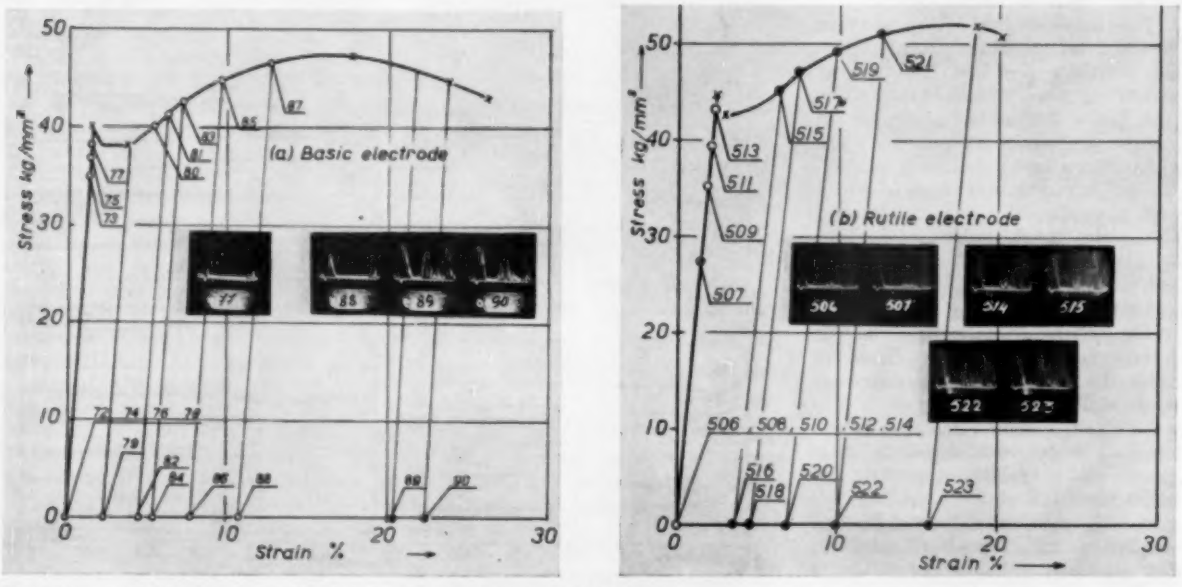


Fig. 8—Ultrasonic identification of fish eyes in tensile testing—(a) basic electrode; (b) rutile electrode. (Open circles: original ultrasonic reflection pattern; filled circles: ultrasonic indication of fish eyes—after Valanti[23])

not occur, may vary greatly from one type of electrode to another as may be seen from Table 3. Although caution should be exercised in generalizing, it appears that a substantial fraction of the hydrogen found in some of these welds cannot be present in true solution. Most likely, a fair amount resides in microcavities in all but the basic deposit E 355 B29.

Since the temporary loss of ductility appears closely connected with the presence of fish eyes in destructive testing, it would be important to know whether such defects can be expected to arise in service. If so, these local spots of brittle fracture might prove to be a dangerous kind of internal notches. A clue to this question may be obtained from work made within the IIW by Valanti.[23] By means of ultrasonic techniques he was able to record local discontinuities in tensile-test bars during the later stages of testing. As an illustration, Fig. 8a and Fig. 8b show typical results for basic and rutile types of electrodes. Both sets of data indicate that ultrasonic echo changes do not occur until the specimen has been stressed beyond the yield point. In the case of the basic electrode where the diffusible hydrogen content was about 2 ml/100 g according to the ASTM procedure, definite evidence of discontinuities was not obtained until the stage of local necking had been reached. In the rutile electrode deposit which had an ASTM content of about 28 ml/100 g, changes in the ultrasonic reflection developed at stresses a little above the yield point, that is, at strains between 4 and 5%. In the absence of notches, plastic deformations of this magnitude are hardly encountered in regular service and are seldom used in normal welding fabrication. In those cases where a certain minimum of ductility must be guaranteed immediately after welding and where it is not practical to apply stress relieving or other kinds of heat treatment, it appears advisable to choose an electrode that will give a weld metal of a sufficient plastic reserve.

The examples quoted above, supplemented with similar data from other sources, may be summarized as follows:

1. A temporary loss of ductility will be expected with all types of low-alloy and mild-steel weld metal, ranging from about 15% to about 40% lowering of the reduction of area.

2. Low and erratic values of elongation and the reduction of area are accompanied by the presence of fish eyes in the fracture.

3. Fish eye formation has been found to initiate at strains in the range from about 4% to about 20% depending on the amount of diffusible hydrogen present.

4. A complete recovery may be expected after a period ranging from a few weeks to a few months, depending on the cross section of the welded joint.

5. About the same improvement may be obtained in a shorter period through artificial aging at 250° C.

6. Threshold values of the total hydrogen content, below which fish eyes do not occur, appear to depend strongly upon the weld metal constitution.

These statements apply to the welding of steels of a low hardenability, when hydrogen embrittlement of the weld metal will be more important than a reduction of ductility of the heat-affected zone. Problems of the latter kind are not considered here.

Permanent Damage Caused by Hydrogen: Microfissures

Microfissures have been shown by Flanigan and others[24-27] and by Bland[28] to develop on rapid cooling of weld metal from cellulose-coated electrodes. Subsequent work has confirmed that such defects may also be expected with other kinds of mild steel electrodes, perhaps with exception of the basic type.[29-31]

It is probable that microfissures arise as a result of microsegregation of hydrogen, as indicated by Flanigan's observation of isothermal immunization and sensitation.[32] A critical level of the average hydrogen content will depend on the cooling rate; as an additional complication, the incidence of fissuring is also affected by restraint. Critical conditions can, therefore, be stated in a very approximate way only. Rollason and Roberts[29] suggest as a practical rule that fissures may be expected in weld metal containing more than 12 ml per 100 g weld metal when the bead is cooled down to 100° C in less than 1 min or, alternatively, when the width of the heat-affected zone is smaller than 2.8 mm. Attempts have been made to evaluate the effects of hydrogen content and of cooling rates by means of controlled cooling similar to that obtained an end-quench test bar.[33] In this way it is possible to define a critical cooling program in terms of "Jominy positions." Testing of commercial rutile-type electrodes has confirmed that the critical cooling program frequently is less drastic than would be expected in the welding of heavy structures.

For practical applications, the effects of microfissures may be assessed by comparison with weld metal deposited under conditions where such defects will not be present. Impaired performance under alternating stresses has been observed in fissured specimens by Sjöthun[34] and by Valanti;[23] recently, Hofmann and Vibrans[35] have reported a reduction of the endurance limit of about 45%. A displacement of the range of transition temperatures is observed in impact testing.[19] The properties measured in tensile testing may be seen from the following data obtained from all-weld-metal bars prepared with two commercial rutile electrodes: E 322 R12 of a total hydrogen content of 33 ml per 100 g, and E 432 R12 containing 25 ml per 100 g. One set of test-bars was prepared with water quenching within 1 min after completion of each pass and another set with an interpass temperature of 250° C. Both sets were heat treated for 16 hr at 250° C prior to testing[36] as indicated in Table 4.

It is seen that the values of elongation and reduction of area are rather poor after rapid cooling. In addition, it will be noted that the ultimate tensile strength and yield point are higher after accelerated cooling. The last two differences are, of course, not caused by the presence of fissures but arise from a more complete recrystallization of each layer in the case of slow cooling, when the interpass temperature was

Table 4—Properties of Heat-treated Test Bars Made from Two Rutile Electrodes

Electrode ISO code	Cooling	Ultimate Tensile Strength, kg/mm²	Yield Point, kg/mm²	Elongation L = 5 × D, %	Reduction of area, %
E 322 R12	Rapid	59	55	15	35
	Slow	52	47	29	63
E 432 R12	Rapid	61	56	16	25
	Slow	55	49	23	40

Table 5—Properties of Normalized Test Bars Made from Two Rutile Electrodes

Electrode	Cooling	Ultimate Tensile Strength, kg/mm²	Yield Point, kg/mm²	Elongation L = 5 × D, %	Reduction of area, %
E 322 R12	Rapid	36	22	20	29
	Slow	41	31	35	63
E 432 R12	Rapid	46	28	19	31
	Slow	48	35	31	49

not allowed to drop below 250° C. A more specific kind of information on the separate effect of fissures may be obtained from a corresponding set of tests of normalized specimens as indicated in Table 5.

The impairment of ductility due to fissures is seen to be roughly equal to that measured on degassed specimens. It is interesting to note, however, that the presence of fissures has in fact reduced the static strength as well. Referred to the properties of sound weld metal, the tensile strength has been reduced by 4 to 10% and the yield point by 20 to 30%.

In the example shown above, single-bead testing after accelerated cooling revealed a number of fissures per centimeter of bead of 10 and 5 respectively in the plane of maximum fissure density. Since the hydrogen content has been shown to be approximately independent of the number of passes, the multirun deposits would be expected to fissure to roughly the same extent. Rollason and Roberts[29] found a greater number of fissures per square centimeter cross section in multirun than in singlerun deposits; however, the nonuniform distribution makes a direct comparison difficult. Metallographic counting of microfissures in single beads has shown that the maximum density may be expected in a section parallel to the plane of the parent plate.[31] A clustering of fissures in the central part of each bead is also indicated in Fig. 9 for a multirun deposit[33] wherein the plane of polish may or may not intersect the regions of maximum density of fissures, depending on the position of the plane. It appears advisable, therefore, to accept a simple single-bead test and, if necessary, to apply suitable corrections to the data obtained in this way. For practical purposes, a test of this kind should not be based on a microscopic examination of a polished section. Instead, it should be based on visual inspection of opened-up fissures in a specimen that has been strained in tension or bending. Such procedures are being tested at present within several IIW countries, with a view to a possible application in the acceptance testing of electrodes.

In summing up the more important features of weld metal microfissures, it may be stated:

1. Microfissures are likely to develop on rapid cooling of weld metal containing more than about 12 ml hydrogen per 100 g of metal. The critical content of hydrogen depends on the cooling program and on the restraint.

2. Microfissures can be completely avoided through slow cooling.

3. The presence of microfissures impairs the ductility, the fatigue strength, the impact toughness and the yield strength.

4. Microfissures are easily detected and counted in single beads. In multilayer deposits difficulties arise from a nonuniform distribution of fissures.

Cracking in the Heat-affected Zone

In contrast to weld metal fissures, defects in the heat-affected zone are encountered in materials of a higher strength only. The application of such materials is increasing rapidly, and it must be expected that under-

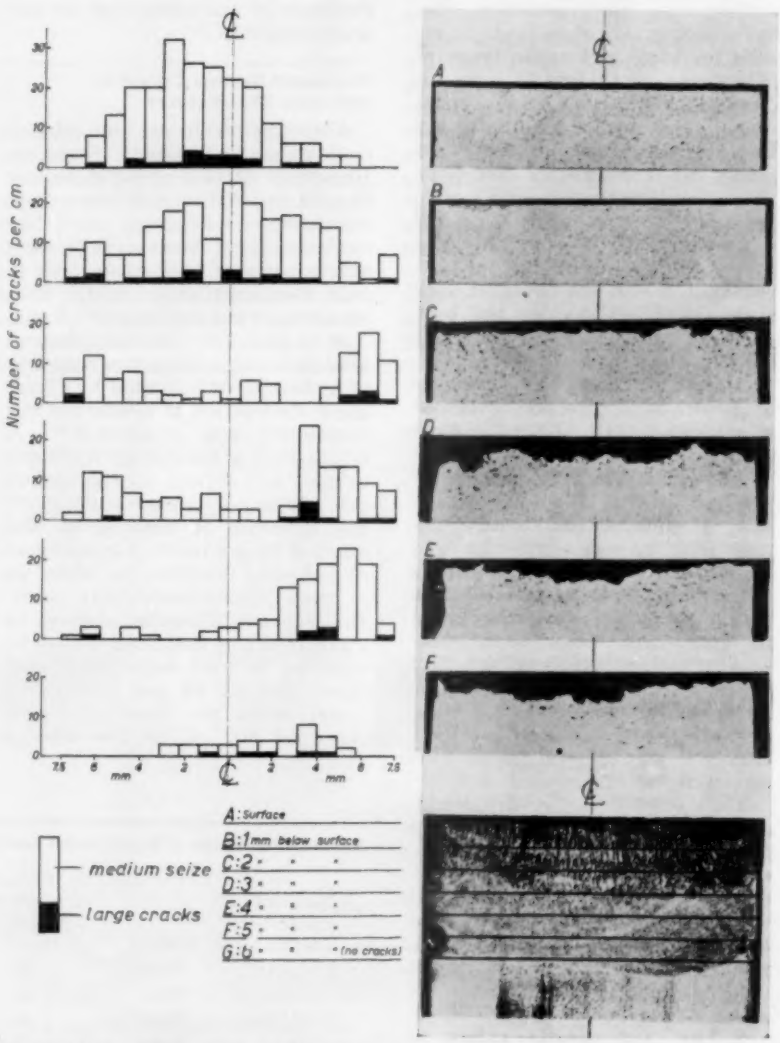


Fig. 9—Measured distribution of microfissures in a multilayer weld[33]

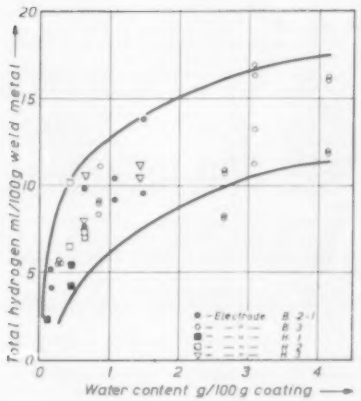


Fig. 10—Hydrogen content of basic weld metal at various contents of water in the coating[36]

bead cracking and other types of hard-zone defects will become increasingly important. Within the IIW, problems of this kind are being studied by Commission IX (Behaviour of Metals Subjected to Welding). So far, Commission II (Arc Welding) has only been concerned with the collection of information on electrodes to be used with medium and high-tensile steels.

In searching for a criterion that might be more readily measured than the total hydrogen content, attempts are being made to explore correlations between weld metal hydrogen contents and potential hydrogen contents, and correlations between these criteria and the susceptibility to under-bead cracking. As a first step in this direction, methods for the measurement of residual water have been reviewed and compared between countries. Using a modified version of the combustion procedure of Gailey and Wooding[37] and the recommended IIW method for the determination of total hydrogen contents,[13] a correlation shown in Fig. 10 has been obtained for electrodes of basic type.[36] Data in the range of low water contents are residual values—that is, the electrodes have been redried as recommended by the maker before testing. The higher levels represent electrodes in the as-delivered state, and water contents above 1% have been obtained by artificial exposure to a humid atmosphere according to a method developed by Smith.[38]

The measured hydrogen contents are seen to scatter within a band of a parabolic shape, as would be expected from theoretical considerations. Disregarding slight variations with respect to composition and volume of the gases produced per gram of dry coating, any addition of water will result in a proportional increase of the partial pressure of ($H_2 + H_2O$). This sum of partial pressures was used in Fig. 1d as a parameter for the calculation of hydrogen dissolved in the bath. For application within one group of electrodes, the water content of the coating thus appears to give a reasonable indication of the total hydrogen content. This conclusion is in accordance with the data reported by Mallett and Rieppel nearly 15 years ago.

Only a fraction of the total hydrogen content reported in Fig. 10 will penetrate into the heat-affected zone. It is not known whether the lateral distribution of hydrogen shown in Fig. 4 for a mild steel will be materially affected by the properties of the steel to be welded, and by such factors as speed of welding and heat input. At the present stage empirical correlations must be resorted to. An example of such correlations is shown in Fig. 11 from data reported by Arikawa.[39] Single beads were deposited on a 25-mm plate of carbon-manganese steel (0.44% C – 0.63% Mn), the temperature of the plate being maintained at −10° C. Again, the early results of Mallett and Rieppel are seen to be confirmed. Cracking occurs at total hydrogen contents above 8 ml/100 g deposit, or at contents of diffusible hydrogen larger than about 5 ml/100 g. These contents correspond to a residual water content between 0.3 and 0.4 g H_2O/100 g coating, as defined by the loss of weight when dried at 400 and 110° C, respectively.

Role of Hydrogen in Acceptance Testing

In concluding this survey of some of the features of hydrogen in metal-arc welding, it may be interesting to see how the increasing knowledge of this subject has been reflected in the philosophy of testing.

In the majority of applications of coated electrodes it will not be economically feasible to reduce the amount of hydrogen present to an insignificant level. Some kind of testing for the evaluation of the harmful effects of hydrogen is clearly needed, but it is not at all obvious how such testing should be arranged. The general approach to this problem within the IIW may be stated as follows, restricting the

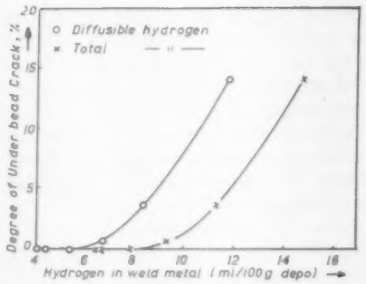


Fig. 11—Example of under-bead cracking in relation to weld metal hydrogen contents—after Arikawa[39]

discussion to mild- and medium-strength steel.

The tensile testing of an all-weld-metal specimen should be considered as a conventional test, designed to supply conventional data for a comparison with other materials of construction. A fair degree of reproducibility should be required in this test to avoid expensive and time-consuming retesting for establishing reliable average values.

These requirements tend to make the all-weld-metal tensile test unsuitable for any evaluation of the effects of hydrogen. First, excessive scattering of the elongation and the reduction of area, caused by the development of fish eyes, should be reduced through a treatment that will take the content of diffusible hydrogen down to such levels as will be reached in a reasonable time by natural aging. This may be done by drawing at 250° C for 16 hr as has been shown. However, in admitting a test to be done after heat treatment rather than in the as-welded state, the results of testing will not be directly applicable to welds that must be able to suffer large amounts of strain immediately after deposition. For such applications the general requirements of ductility should be adjusted accordingly.

Next, any susceptibility to microfissuring will be completely concealed by the use of an average interpass temperature of 250° C. The properties measured with specimens prepared in this way will be representative of welded joints that have been allowed to cool rather slowly. It cannot be safely assumed that the welds in a heavy structure will perform as predicted from the tensile test, and some additional method of testing will be required.

In principle, information on the effects of microfissures could be obtained from a tensile bar pre-

pared under controlled conditions of rapid cooling. A cheaper method, and one that might give as much information, consists in an examination of a single bead for the presence of microfissures. A proper grading for various quality classes may be achieved through a proper adjustment of the cooling conditions or, alternatively, through a specification of the maximum number of fissures permitted.

The principle suggested for the testing of microfissures implies that a sound weld is safe if it shows a specified amount of ductility in destructive testing. The criterion of soundness, as an additional requirement to the conventional data assessed in an all-weld-metal tensile test, will probably play an even more important role in the case of welded joints in high-strength materials. In general, it is believed that a study of defects and their mechanism of formation will prove a most fruitful approach to problems caused by the presence of hydrogen.

The present situation, with regard to those sides of the subject which have been discussed above, may perhaps be summarized as follows.

1. The main sources of hydrogen are known and can be controlled to a fair extent.

2. Methods are available for a reasonably reliable determination of average hydrogen contents. Information is lacking on the distribution of hydrogen in the weld and its surroundings, and on the distribution on a microscopic scale. Very little is known about the physical states of hydrogen in weld metal.

3. From a practical point of view, the harmful effects of hydrogen can be handled in the case of mild- and medium-strength steel by means of properly adjusted welding conditions and a proper choice of electrodes. A further development of extra-low-hydrogen electrodes might prove sufficient for the welding of high-strength materials; however, additional precautions in the form of preheating and postheating will probably be necessary in some cases.

4. It is felt that additional testing for the assessment of the effect of hydrogen is needed even in the case of mild and low-alloy-steel electrodes. As a consequence, additional testing of this kind will most probably be included in a recommended procedure for acceptance testing now under preparation within the International Institute of Welding.

Acknowledgment

The author wants to thank his colleagues within the International Institute of Welding, in particular the members of Subcommission A of the Arc Welding Commission, whose research reports have been freely used as illustrations. He is also indebted to his colleagues on the metallurgical staff of SINTEF for their investigations in the present field, and to the Royal Norwegian Council for Scientific and Industrial Research, for financial support of these investigations.

References

1. Sloman, H. A., Rooney, T. E., and Schofield, T. H. *Jnl. Iron Steel Inst.* **152** 127P–153P (1945).
2. Mallett, M. W., and Rieppel, P. J., THE WELDING JOURNAL, **25**, (11), Research Suppl., 748-s to 759-s (1946).
3. Mallett, M. W., *Ibid.*, **25**, (11), Research Suppl., 396-s to 399-s (1946).
4. van den Blink, W. P., *Ibid.*, **26**, (7), Research Suppl., 369-s to 370-s (1947).
5. Reeve, L., *Metallurgy of Steel Welding*, p. 48–54, Brit. Weld Res. Assn., London (1948).
6. Christensen, N., THE WELDING JOURNAL, **28**, (8), Research Suppl., 373-s to 380-s (1949).
7. Christensen, N., and Gjermundsen, K., unpublished.
8. Rykalin, N. N., *Berechnung der Wärmevorgange Beim Schweissen* (Verlag Technik, Berlin, 1957).
9. Geller, W., and Tak-Ho-Sun. *Archiv Eisenhüttenwes.* **21**, 423–440 (1950).
10. Christensen, N., Gjermundsen, K., and Rose R., *Brit. Weld. Jnl.* **5** 272–281 (1958).
11. Roux, A., *Rev. Mét.* **21**, 192–202 (1954).
12. Blake, P. D., *Brit. Weld. Jnl.* **5**, 127–129 (1958).
13. "Determination of Total Hydrogen Contents in Weld Metal," Document IIW/IIS-8-58. See, e.g., *Brit. Weld. Jnl.* **6**, 87–89 (1959).
14. Cottrell, C. L. M., private communication.
15. Blake, P. D., *Brit. Weld. Jnl.* **4**, 146–154 (1957).
16. Araki, I., and Ichihara, I., "Behaviour of Hydrogen in Weld Metal," Report Submitted to the Commission II (Arc Welding) at the Annual Assembly 1959.
17. ASTM Designation A 316-48 T.
18. Moneyron, M., and Séférian, D., *Soud. Tech. Conn.*, **11** 277–289 (1957).
19. Christensen, N., Augland, B., and Rose, R., Progress Report submitted to the Royal Norwegian Council for Scientific and Industrial Research, December 1957 (with supplementary data submitted September 1958).
20. Hummitzsch, W., Document IIW/IIS-5-58. See also *Stahl Eisen* **77**, 279–290 (1957); *Schweissen und Schneiden* **9**, 386–390 (1957); *Ibid.*, **10** 476–480 (1958).
21. "Method of testing and approval of electrodes for welding of carbon and low alloyed high tensile steels," IIW Document II-64-59 (recommended for publication).
22 Pfeiffer, C., IIW Document II-113-60 (recommended for publication).
23. Valanti, V. O., *Hitsaustekniikka* (*Svetstekniik*), No. 4, 102–136 (1957).
24. Flanigan, A. E., THE WELDING JOURNAL **26**, (4), Research Suppl., 193-s to 214-s (1947).
25. Flanigan, A. E., Bocarsky, S. J., and McGuire, G. B., *Ibid.*, **29**, (9), Research Suppl., 459-s to 466-s (1950)
26. Flanigan, A. E., and Kaufman, M., *Ibid.*, **30**, (12), Research Suppl., 613-s to 622-s (1951).
27. Flanigan, A. E., and Micleu, T., *Ibid.*, **32**, Research Suppl., 99-s to 106-s (1953).
28. Bland, J., *Ibid.*, **25**, (5), Research Suppl., 216-s to 226-s (1949).
29. Rollason, E. C., and Roberts, R. R., *Jnl. Iron Steel Inst.*, **166**, 105–112 (1950).
30. Warren, W. G., and Vaughan, H. G., *Trans. Inst. Weld.*, **16**, 127–135 (1953).
31. Christensen, N., and Rose, R., *Brit. Weld. Jnl.*, **2**, 550–558 (1953).
32. Flanigan, A. E., and Saperstein, Z. P., THE WELDING JOURNAL, **35**, (11), Research Suppl., 541-s to 556-s (1956).
33. Christensen, N., *Hitsaustekniikka* (*Svetstekniik*, No. 5–6, pp. 118–120, 116, and 141–143 (1958).
34. Sjöthun, H., unpublished Metallurgical Engineer's Thesis, Norges tekniske högskole (1958).
35. Hofman, W., and Vibrans, G., *Schweissen und Schneiden* **12**, 95–101 (1960).
36. Christensen, N., Schou, E., unpublished.
37. Gailey, C. T., and Wooding, D. H., THE WELDING JOURNAL, **29**, (8), 629–635 (1950).
38. Smith, D. C., *Ibid.*, **36**, (7), 677–692 (1957) (1957 Adams Lecture).
39. Arikawa, M., Report submitted to the IIW Sub-Committee IIA (Feb. 1960).

Notice—Annual University Research Conference of Welding Research Council

The University Research Committee of Welding Research Council will hold its Annual Conference this year on *Wednesday evening, April 19, 1961 at 8 P.M. in the Windsor Terrace room of the Hotel Commodore, New York City.*

In order to encourage more basic research in welding processes, the Committee has planned a 2-paper symposium on Arc Physics Research. The authors are the world renowned Dr. H. J. Olsen from the United States, and J. C. Amson from England. The Committee cordially invites research men from industry and government agencies, as well as from the universities, to attend this symposium.

Hydrogen and Delayed Cracking in Steel Weldments

Hydrogen and restraint cause delayed cracking, and susceptibility is greater for higher strength materials

BY E. P. BEACHUM, H. H. JOHNSON AND R. D. STOUT

ABSTRACT. Investigation was centered on the combined effects of hydrogen and stress on delayed cracking in steel welds of several common compositions, both carbon and alloy. The primary tool was the Lehigh restraint test. The inert-gas consumable-electrode welding process was used with hydrogen introduced in free and combined forms.

Cracking time was found to depend on base plate, welding wire composition, restraint and hydrogen; but the relations among these variables are complex. Cracking time was observed to lengthen at low aging temperatures, which suggests strongly that hydrogen diffusion is an important aspect of the delayed cracking mechanism. Weldment hydrogen contents for various welding conditions and a particular base plate-weld metal combination were determined by both immersion and hot vacuum extraction methods.

It is concluded: (*a*) hydrogen and restraint can cause weldment delayed cracking, (*b*) susceptibility is greater for the higher strength base plates and weld metals, (*c*) residual hydrogen content does not correspond closely with welding gas composition.

Introduction

Delayed cracking in steel weldments is a serious problem because it frequently escapes detection by ordinary inspection procedures. Delayed cracking may occur either in the weld bead or in the heat-affected zone. Steinberger and Stoop[1] have illustrated weld cracks which were not apparent until after time periods ranging from 3 to 24 hr.

Delayed cracking is not restricted to weldments as shown by reports of delayed failures in rotor forgings and also rocket motor casings, both under conditions which precluded ordinary fatigue. Careful investigation by Dana, Shortsleeve and Troiano,[2] pointed to a form of hydrogen embrittlement known as "flakes" as the cause of the rotor failures. Shank and associates[3] concluded that the casing failures were the result of hydrogen embrittlement in which the hydrogen was introduced by a kind of stress corrosion.

Detailed studies of underbead cracking in steel weldments have conclusively indicated hydrogen to be a prime causative agent. Mallett and Rieppel,[4] studying underbead cracking of welds cathodically charged with hydrogen, concluded that both retained austenite and a significant hydrogen concentration were necessary for the formation of underbead cracks.

It has been suggested by Flanigan[5] and others that the incidence of microcracks in welds on aging is related to the hydrogen concentration in the weld metal. Berry and Allan,[6] working with gaseously-charged welds, have recently connected weld cracking with hydrogen content and cooling rate.

Recent studies by Johnson, Morlet and Troiano,[7] using notched tensile specimens cathodically charged with hydrogen, have suggested that an interaction between hydrogen concentration and triaxial stress state controls crack initiation and propagation. The incubation period was associated with the diffusion of hydrogen. Thus the implication is strong that delayed cracking of welds is associated with the presence of hydrogen. In such case one would expect the phenomenon to be diffusion controlled.

The present work was designed to assess the contribution of hydrogen to delayed cracking of welds by the addition of controlled amounts of hydrogen directly to the welding arc atmosphere. So far as practicable, industrial welding conditions were maintained in these tests. This is a progress report on an investigation still under way.

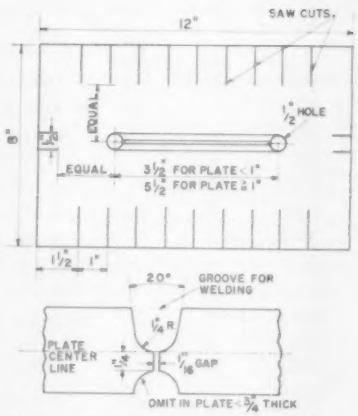


Fig. 1.—Lehigh restraint test—Stout, Tör, McGeady and Doan[8]

Materials and Procedure

The investigation was centered on the combined effects of hydrogen and stress on the cracking of steel welds of several common compositions, both carbon and alloy. Compositions of the plates used are given in Table 1; compositions of the wires used are given in Table 2. The carbon steel plates were tested in the as-rolled condition; the alloy steel plates were in either the normalized or quenched and tempered condition.

The testing method was the Lehigh restraint test—Fig. 1—which provides a convenient method of varying the stress in the weldment. A simple but sensitive microswitch and timer device was used to measure the delay time before cracking.

The inert-gas consumable-electrode welding process was used with hydrogen introduced by three methods:

1. Mixing hydrogen with argon

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Paper to be presented at AWS 42nd Annual Meeting to be held in New York, N. Y., Apr. 17-21, 1961.

Table 1—Compositions of Steel Plates (% by Weight)

	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al	N	H	O
AISI 1020	0.20	0.52	0.018	0.019	0.14	0.22	0.10	0.11	0.03	0.033	0.012	11×10^{-6}	0.0081
ASTM A212	0.32	0.71	0.02	0.021	0.24	...	0.02	0.03	0.01	0.005	0.005	1×10^{-6}	0.0067
Navy HY-80	0.15	0.26	0.011	0.021	0.25	...	2.95	1.83	0.48	0.040	0.010	2×10^{-6}	0.00145
AISI 4140	0.38	0.78	0.016	0.029	0.32	0.07	0.03	0.95	0.22	0.017	0.011	3×10^{-6}	0.0025

Table 2—Compositions of Welding Wires (% by Weight)

	C	Mn	P	S	Si	Ni	Cr	Mo	V	Al	Ti	Zr	N	H	O
Code A	0.05	1.48	0.015	0.014	0.56	0.09	0.03	0.02	...	0.06	0.10	0.04	0.008	21×10^{-6}	0.0257
Code B	0.12	1.27	0.016	0.025	0.47	0.09	0.06	0.04	...	0.052	...	...	0.009	13×10^{-6}	0.0135
Code C	0.05	1.32	0.009	0.012	0.55	1.32	0.09	0.43	0.15	...	...	...	0.011	7×10^{-6}	0.0104

Table 3—Summary of Delayed Cracking Tests—Carbon and Alloy Steels

Steel	Wire code	Restraint, in.	Atmosphere	Cracking time, hr	Remarks
1020	A	8	Ar + 15.5% H_2	No crack	3 in. bead
1020	A	8	+ 2.5% C_2H_2	1.9	3-in. bead
1020	A	7	+ 2.5% C_2H_2	No crack	3-in. bead
1020	B	8	+ 10% H_2	No crack	3-in. bead
1020	B	6	+ 12% H_2	0.33	3-in. bead
1020	B	8	+ sat. H_2O	1.7	3-in. bead
A212	A	8	Ar + 5% H_2	No crack	3-in. bead and groove
A212	A	8	+ 7.5% H_2	9.45	
A212	B	8	Specially dried Ar	No crack	3-in. bead and groove
A212	B	8	Ar + 4% H_2	No crack	
A212	B	8	+ sat. H_2O	1.5	
A212	B	8	+ 7.5% H_2	0.5	3-in. bead and groove
A212	B	7	+ 7.5% H_2	0.7	
A212	B	6	+ 7.5% H_2	No crack	
A212	C	8	+ 7.5% H_2	0.35	
HY-80	A	8	Ar + 5% H_2	34.4	3-in. bead and groove
HY-80	B	8	+ 5% H_2	0.7	3-in. bead
HY-80	C	8	Com. pure Ar	No crack	
HY-80	C	8	Ar + 0.5% C_2H_2	0.4	
HY-80	C	8	+ 3% H_2	0.45	
HY-80	C	8	+4% H_2	0.4	
HY-80	C	8	+ 5% H_2	0.5	
HY-80	C	8	+ sat. H_2O	1.1	
HY-80	C	7	+ sat. H_2O	1.1	
HY-80	C	6	+ sat. H_2O	No crack	
HY-80	C	8	+ 5% H_2	3.35	Vibrated 1 hr
HY-80	C	8	Specially dried Ar	No crack	Water quenched
HY-80	C	8	Com. pure Ar	2.3	Water quenched
HY-80	C	8	Ar + 2% H_2	0.35	Water quenched
HY-80	C	8	+ 4% H_2	0.3	Aged in dry ice box
HY-80	C	8	+ 4% H_2	2.0	Precool, aged in dry ice box
HY-80	C	8	+ 4% H_2	6.6	Precool − 50° F, quenched and aged in − 50° F bath
HY-80	C	8	+ 5% H_2	4 + 2	Precool, quenched and aged − 110° F 4 hr
HY-80	C	8	+ 5% H_2	8 + 0.25	Same, except aged − 110° F 8 hr
4140	A	3	Ar + 2.5% H_2	4.3	High energy
4140	B	8	+ 2% H_2	1.65	
4140	C	8	Specially dried Ar	2.5	High energy
4140	C	4	Specially dried Ar	7.75	High energy
4140	C	4	Ar + 5% H_2	0.3	High energy
4140	C	3	+ sat. H_2O	7.6	High energy

NOTE: All tests had 5-in. bead and groove unless otherwise indicated.

to the desired amount.
2. Bubbling argon through water to saturate it.
3. Mixing propane with argon to the desired amount.

Most welds were run at an energy level of 30 kilojoules per in., ±10%; a few were run at a level 50% higher. A root penetration of about 0.15 in. was the aim, but the range of welding conditions employed necessarily introduced some variation. As expected, the weld area was proportional to the heat input within any one type of arc atmosphere.

Weldment hydrogen contents for various welding conditions and a base plate weld metal combination were determined by both immersion and hot vacuum extraction methods. The scatter in both methods was broad. Efficiency of hydrogen absorption was investigated for beads in grooves as well as on flat plates. The immersion method used to measure "diffusible" hydrogen was similar to a mineral oil method developed elsewhere;[9] this produced consistent, although probably only relative results.

The effect of temperature of aging on cracking time was investigated. Tests at low temperature were carried out by immersion in a bath of dry ice and alcohol. Vibrational energy was added after welding to one test by means of a commercial sonic oscillator at the resonant frequency.

Cooling curve studies were made to determine the time at which the temperature becomes uniform in the specimen and restraint ceases to increase, or even decreases. Any crack which formed after this time was defined as a delayed crack.

Preparation for metallographic examination was carried out using diamond dust abrasive, which gave results equivalent to electropolishing.

Results and Discussion

Definition of Delayed Cracking

Cooling curve studies indicated that, within 15 min after welding, the temperatures and also the cooling rates at the edge, midpoint and groove had become substantially equal. Furthermore, at the end of this time the temperature did not exceed 150° F at any point, even when high heat input was used. The criterion for delayed cracking was accordingly taken as cracking after an elapsed time of 0.25 hr or more. Weld cooling rates observed varied from 63–95° F per sec at 1000° F, and from 5–19° F per sec at 500° F.

Originally it was intended to confine the study to weld metal cracks. However, it soon became apparent that weld metal cracking could not be entirely separated from underbead cracking—at least in the Lehigh restraint test. The carbon steel tests nearly always cracked in the weld metal. Cracks in the HY-80 tests usually started near the fusion line in the heat-affected zone but finished in the weld metal. The AISI 4140 tests cracked deep in the underbead area. In HY-80, this pattern could be influenced by the choice of atmosphere, moisture tending to increase the amount of underbead cracking as compared to hydrogen gas. Complete test data are presented in Table 3.

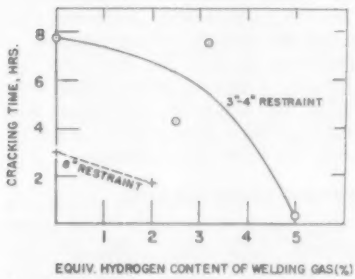

Fig. 2—Cracking time as function of hydrogen and restraint—AISI 4140 steel

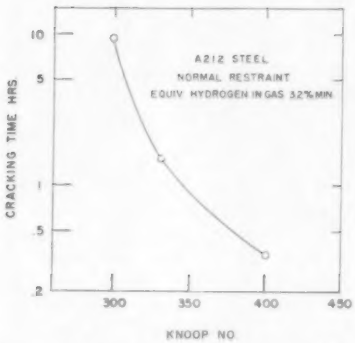

Fig. 3—Log cracking time as a function of fracture root hardness—normal restraint in carbon steel, equivalent hydrogen in gas not less than 3.2%

Effect of Hydrogen and Weld Metal Composition

With arc atmospheres of commercially pure argon (in some instances with additional drying), it was possible to obtain crack-free welds deposited under the full 8 in. restraint in the 1020, A212 and HY-80 steels. The 4140 steel cracked in every case, even in specimens cut to 3 in. restraint.

In tests on the carbon steels and HY-80, additions of hydrogen produced delayed cracking only above a threshold level (which varied for the steel, electrode and restraint level). Further additions of hydrogen did not appear effective. In the case of 4140 steel, delay in cracking was reduced as the level of hydrogen in the welding gas was raised. This is illustrated by Fig. 2 for two restraint levels. Note that less hydrogen was required at 8 in. restraint to equal its effect on specimens with 4 in. restraint.

The effect of the electrode composition was found to be related principally to its contribution to the hardness level of the weld deposit. In specimens of A212 steel, which displayed delayed cracks in weld metal, the elapse of time before cracking decreased as the hardness of the deposit increased. Figure 3 illustrates this point.

The importance of the hardenability of the electrode composition is demonstrated further in Fig. 4. The extent of the delay in cracking is shown to decrease as the calculated hardenability of the electrode is raised, even for tests in which cracking was largely in the heat-affected zone.

The interaction of hydrogen and the hardness level of the metal at the site of delayed cracking is summarized in Fig. 5. A wide variety of combinations of plates, electrodes and hydrogen contents in the welding gas are represented by the plotted points. These points lie above a minimum envelope below which no cracking was observed. Roughly, the Knoop hardness plus 20 times the percent equivalent hydrogen in the gas had to exceed 400 to produce cracking in full-restraint specimens or 500 in 4-in. restraint specimens.

Effects of Subzero Aging and Vibration

The phenomenon of delayed cracking suggests that a diffusion process is a part of the mechanism causing cracking. The effects of hydrogen observed in this study indicate hydrogen diffusion may be responsible for the time element in crack formation.

One means of detecting the role of diffusion is to lower the temperature of the test piece to reduce the rate of diffusion. A series of specimens of HY-80 steel were welded with 4–5% hydrogen in

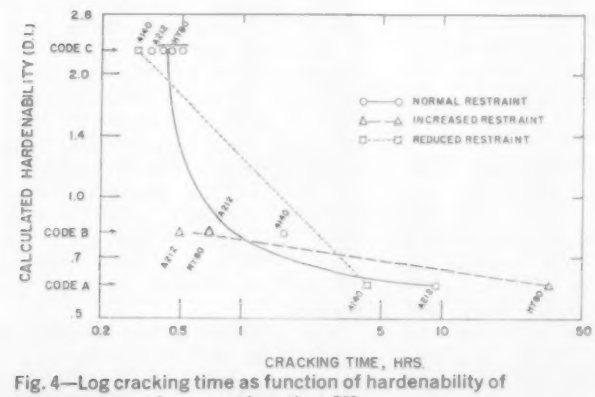

Fig. 4—Log cracking time as function of hardenability of wire—hydrogen in gas not less than 2%

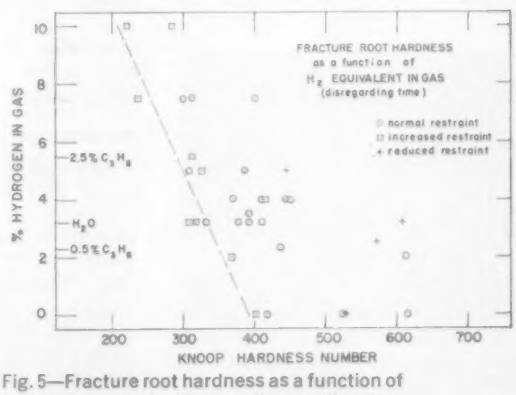

Fig. 5—Fracture root hardness as a function of hydrogen equivalent in gas, disregarding time

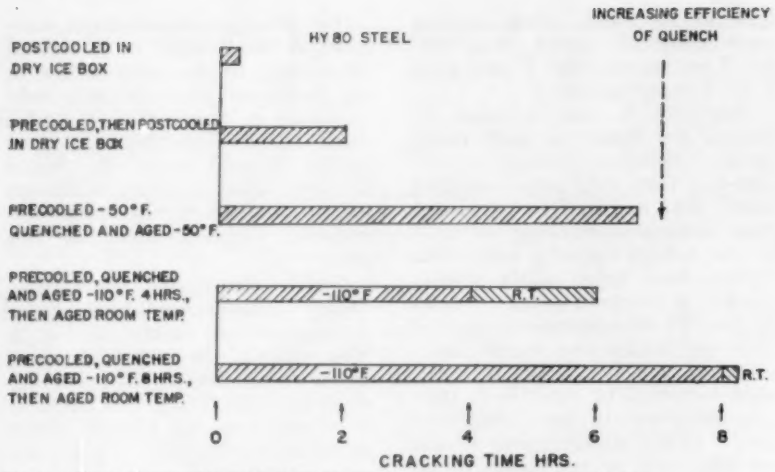

Fig. 6—Effect of quenching and low temperature aging on cracking time—HY-80 steel at 4–5% hydrogen level

argon. The cooling time after welding was shortened by cooling specimens in a cold cabinet or dry-ice and alcohol bath. The results are tabulated in Table 3 and presented graphically in Fig. 6. The point to be noted is that both precooling and postcooling were effective in delaying the formation of cracks. At −110° F, no crack appeared during 8 hr of exposure, but the specimen cracked 1/4 hr after returning to room temperature.

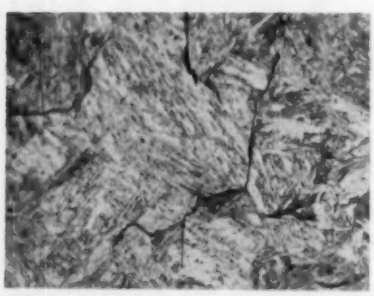

Fig. 7—Longitudinal microcracks in HY-80 test at 4% H_2 level, aged at −50° F, × 500 (Reduced 45% on reproduction)

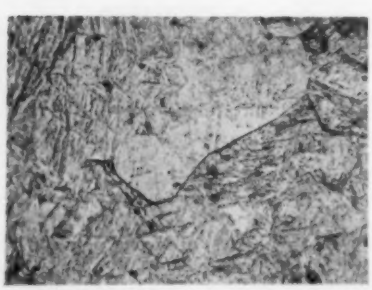

Fig. 8—Transverse microcrack in HY-80 test at 3.5% H_2 level showing variation in structure, × 500 (reduced 45% on reproduction)

Thus cracking was effectively suppressed at low temperatures, in keeping with the concept of a diffusion controlled mechanism.

Working with cathodically-charged notched tensile specimens, Steigerwald, Schaller and Troiano[10] concluded that, as the testing temperature was lowered, the crack incubation time constituted an increasing percentage of the total fracture time until, at −50° F, the two were coincident. Using the method developed by these authors, the activation energy for hydrogen diffusion was calculated, at the 4% hydrogen level, from the cracking times at room temperature and at −50° F. An activation energy of 6090 cal. per g-atom was obtained, which is in relatively good agreement with the value of 9120 reported by Steigerwald and associates.

A second test method which suggested an effect of diffusion rate on cracking was the use of sonic vibration immediately after welding for 1 hr. The oscillating energy extended the delay time from 0.5 to 3.4 hr. It is possible that the vibration served to scatter the hydrogen out into the plate and effuse some of it.

Metallographic Studies

Microscopic examination indicated that delayed cracks did not occur unless some martensite was present in the bead or heat-affected zone, except for one instance in which bainite was present. Furthermore, microcracks were not observed unless the structure was substantially martensite or low-temperature bainite, and then only in tests which fractured. (Not all fractured tests contained microcracks discernible at × 500.) When present, microcracks occurred in the weld bead, usually near the fusion line, except in a few cases. In the vibrated test of HY-80, the microcracks were centrally located in the weld; in the test of this steel aged at −50° F, flake-like cracks were observed in the heat-affected zone as well as in the weld. Both longitudinal and transverse cracks were found—Figs. 7 and 8. Microcracks were not found in the AISI 4140 steel, but multiple fracture paths were present.

The presence of retained austenite was not thoroughly checked by X-ray diffraction. However, in a few tests of HY-80 steel welded with the Code C wire, some indication of retained austenite was found in the weld bead although not in the heat-affected zone.

Hydrogen Absorption Tests

Hydrogen absorption tests using gaseous hydrogen indicated the absorption efficiency to be nearly constant. As hydrogen in the gas was increased, the "diffusible" hydrogen (recoverable at room temperature) increased proportionately. When argon saturated with water vapor was used, the diffusible hydrogen corresponded to that obtained with 3.2% hydrogen in the argon, which is considerably higher than indicated by the vapor pressure of water at the gas temperature of approximately 50° F, about 1.2% H_2O. This result is interpreted to be caused by the higher activity of hydrogen in the combined form.

For propane additions between 1.1 and 2.5%, the efficiency of hydrogen recovery from the gas was about 75% that of hydrogen at 1.1%, and decreased as the propane in the gas was increased.

"Residual" hydrogen (hot extraction) measurements did not show a significant relation to the hydrogen concentration in the gas. On the average, they were approximately the same as for welds made in commercially pure argon. Investigations of the distribution of hydrogen around a weld indicated that, in welds deposited with commercially pure argon, the weld metal hydrogen content exceeded the sum of the initial hydrogen contents available from the base plate, welding wire and gas. The extra hydrogen may have come by diffusion of moisture through the gas hose.

The diffusible hydrogen contents obtained by this adaptation of the inert-gas process are considerably smaller than those usually reported

for cellulose-coated electrode welding. This is in keeping with the much larger percentage of hydrogen in the welding atmosphere of the coated electrodes, i.e., the fact that the hydrogen is exclusively in combined form and that the coating is fed into the arc along with the electrode.

The residual hydrogen measurements agree with values reported by Blake,[11] and others. Blake considers the residual hydrogen to be trapped mostly in voids. Such trapped hydrogen is probably molecular and requires energy for its dissociation. Evidently delayed cracking results from mobile hydrogen, which is presumably in the atomic or protonic form. The present study shows that, after allowing for the immobilized residual hydrogen, cracking can be caused by very small amounts of hydrogen in the steel.

Mechanism of Delayed Cracking

As previously noted, a distinctive fracture mode was observed with each of these steels. The greater the hardenability of the plate, the deeper in the heat-affected zone the fracture path was observed to lie. It is postulated that the relative hardenability of the weld bead and heat-affected zone is a major factor in determining where the fracture will originate. As has been pointed out by Nippes,[12] if the cooling rate is sufficiently drastic, a uniform, low-carbon martensite can be produced; but below some critical rate a mixture of ferrite and high-carbon martensite or bainite is produced, which has been found to be crack sensitive. The observed cooling rates of the weld groove were all high enough to produce low-carbon martensite. However, at some variable distance in the heat-affected zone the critical cooling rate must have occurred to produce a crack-sensitive structure where the fracture could originate.

The greater the hardenability of the plate, the deeper in the heat-affected zone should be the point where this critical structure occurs. Also, the amount of mixed structure required to lower the ductility to the critical value would be expected to be less, the higher the strength of the steel. However, the presence of hydrogen can in itself act to stabilize the austenite in some steels, as suggested by Kumar and Quarrell,[13] and thus influence the location of the critical section for crack initiation. According to this theory, then, while delayed cracking would result from accumulation of hydrogen at sites of triaxial stress by diffusion,[7] the fracture would tend to originate in an area of low ductility. In the higher strength steels, even a slight reduction in ductility might be sufficient for this purpose, and the amount of high-carbon martensite required could be quite small.

In the Lehigh restraint test, the mechanical notch at the weld root can create stress concentration sites. In the hardenable grades, high-speed dilatometer studies have shown residual transformation strains to be present.[14] Both could start the process of hydrogen diffusion by providing sites of local stress concentration superimposed on the general restraint stress pattern. Hydrogen segregation follows the austenite transformation pattern as the result of higher solubility in the gamma-phase, thus ending in the heat affected zone in the hardenable steels, the last spot to transform.

According to this hypothesis, cracking time would be related to:

1. Presence of high-carbon martensite which, because of its low ductility, would be expected to require less hydrogen to initiate cracking and consequently less diffusion.

2. Length of diffusion path, which in turn would be related to overall hydrogen level and the number of triaxial stress sites.

3. Presence of retained austenite, which if stable can dissolve considerable hydrogen but may decompose isothermally, reject its hydrogen, and disturb the stress pattern in its vicinity.

4. A threshold level of restraint, below which cracking does not occur, and above which cracking may occur in shorter time as restraint increases. The lower the ductility of the weld zone, the less is the restraint required to cause cracking.

Conclusion

The results of this investigation can be summarized as follows:

1. Hydrogen, coupled with restraint and introduced into a weld as gaseous hydrogen, in water vapor, or in propane, caused delayed cracking. The amount of hydrogen required was small.

2. As fracture root hardness increased, less hydrogen was required for cracking to occur. At a given hydrogen content of the gas, restraint lowered the hardness level at which cracking occurred.

3. At the lower aging temperatures the cracking time was longer and thus in keeping with the known facts of diffusion.

4. Cracking time was extended by imposing an oscillating energy pattern on the weld, possibly by impeding diffusion to stress sites.

5. Recovery of diffusible hydrogen was proportional to the hydrogen in the gas within the range studied. Residual hydrogen determinations did not show a high degree of correlation with hydrogen in the gas.

6. When combined hydrogen was added to the gas, the recovery differed from that obtained for equivalent gaseous hydrogen. Water vapor increased the recovery. When propane was added, the recovery of hydrogen was less.

7. A weldment made with commercially pure argon contained more hydrogen than could be accounted for by the initial hydrogen in the plate, wire and gas.

Acknowledgments

The authors wish to express their appreciation to the University Research Committee of the Welding Research Council for sponsoring this investigation. The cooperation of the Bethlehem Steel Co. in assisting with the testing is also gratefully acknowledged.

References

1. Steinberger, A. W., and Stoop, J., "Studies of the Crack Sensitivity of Aircraft Steels," THE WELDING JOURNAL, **31**, Research Suppl., 527-s to 542-s (1952).

2. Dana, A. W., Shortsleeve, F. J., and Troiano, A. R., "Relation of Flake Formation in Steel to Hydrogen, Microstructure and Stress," *Trans. AIME*, **203**, 895-905 (1955).

3. Shank, M. E., Spaeth, C. E., Cooke, V. W., and Coyne, J. E., "Solid Fuel Rocket Chambers for Operation at 240,000 PSI and Above," *Metal Progr.*, **76** (5), 74-81; (6), 84-92 (1959).

4. Mallett, M. W., and Rieppel, P. J., "Underbead Cracking of Welds Cathodically Charged with Hydrogen," THE WELDING JOURNAL **29** (7), Research Suppl., 343-s to 347-s (1950).

5. Flanigan, A. E., and Kaufman, M., "Microcracks and the Low Temperature Cooling Rate Embrittlement of Welds," *Ibid.*, **30**, Research Suppl., 613-s to 622-s (1951).

6. Berry, J. T., and Allan, R. C., "A Study of Cracking in Low-alloy Steel Welded Joints," *Ibid.*, **39** (3), Research Suppl., 105-s to 116-s (1960).

7. Johnson, H. H., Morlet, J. G., and Troiano, A. R., "Hydrogen, Crack Initiation and Delayed Failure in Steel," *Trans. AIME*, **212**, 528-536 (1958).

8. Stout, R. D., Tör, S. S., McGeady, L. J., and Doan, G. E., "Quantitative Measurement of the Cracking Tendency in Welds," THE WELDING JOURNAL, **25** (9), Research Suppl., 522-s to 531-s (1946).

9. Scott, T. E., and Troiano, A. R., "Hydrogen and Segregates in Flaking," *Trans. AIME*, **215**, 619-622 (1959).

10. Steigerwald, E. A., Schaller, F. W., and Troiano, A. R., "Discontinuous Crack Growth in Hydrogenated Steel," *Ibid.*, **215**, 1048-1052 (1959).

11. Blake, P. D., "Measurements on the Diffusible, Residual, and Total Hydrogen Contents of Weld Metal," *British Welding Jnl.*, 12-15 (March 1958).

12. Nippes, E. F., "The Weld Heat-Affected Zone," WELDING JOURNAL, **38** (1), Research Suppl., 1-s to 18-s(1959).

13. Kumar, R., and Quarrell, A. G., "Effect of Hydrogen on Martensite Formation in Low-Alloy Steels," *Jnl. Iron Steel Inst.*, **187**, 195-204 (1957).

14. Bubba, L., "High Speed Dilatometric Analysis of Structural Steels," Unpub. M.S. Thesis (1960), Lehigh University.

Properties of Flash-Welded Molybdenum

Arc-cast molybdenum with 0.5% titanium is successfully joined in air; welds can be hot worked

BY ERNEST G. THOMPSON, HAROLD BINDER AND HAROLD COLLINS

ABSTRACT. A technique for the flash welding of arc-cast 0.5% titanium-molybdenum alloy bar stock has been developed. The as-welded properties of the joint have been determined at room temperature. Flash-welded bars have been processed into sheet material, and the properties of the cold-worked specimens have been ascertained over the temperature range of 2200 to 3200° F.

The feasibility of applying the flash-welding process to the fabrication of molybdenum alloy rings and cylinders was demonstrated. Such parts can be used as structural members, or, more importantly, as preforms for production of hardware by metal-moving techniques.

Introduction

At room temperature, commercial arc-cast molybdenum has reasonable ductility in the severely cold-worked condition. As-cast or recrystallized material behaves in a brittle manner. The lack of ductility in the as-cast condition has proved to be caused by quantities of oxygen and, to a lesser extent, nitrogen as measured in the parts per million range.[1] The effects of recrystallization and grain size on the ductility exhibited by molybdenum has been reported by Bechtold.[2]

The utilization of flash welding has certain advantages which should result in optimum obtainable joint properties. Because the time required to create the weld is short and because the upsetting forging action during welding expels all molten and some plastic material, the possibility of weld contamination is reduced. Furthermore if properly made, the joint created consists of a fine-grained, recrystallized and partially worked microstructure. The elimination of a cast structure and the potential improvement in the ductility of the recrystallized microstructure of the weld by a significantly finer grain size are the advantages of flash welding compared with fusion welding.

In addition to apparent process advantages, the difficulty in obtaining, and the expense of, large forged rings or extruded cylinders make flash-welded hardware desirable. Such hardware could be fabricated into sheet metal parts by various spinning techniques, enhancing the weld joint properties by cold working.

For the foregoing reasons, a program was initiated to investigate the possibility of utilizing flash welding in the fabrication of molybdenum parts.

A summation of efforts to weld molybdenum by various processes has been presented by Nippes and Chang.[3] With respect specifically to flash welding, Sohn[4] reports briefly that flash welds can be made joining pure molybdenum which have 100% joint efficiency based on yield tensile strength. Papers[5, 6] on the flash welding of commercial molybdenum which report the findings of an investigation conducted at Rensselaer Polytechnic Institute are probably the only extensive works on the subject published in this country.

The Rensselaer program studied the quantitative effects of burn-off, clamping distance and platen acceleration on the temperature distribution during parabolic flashing. During the initial stages of flashing, instantaneous temperatures in the vicinity of the weld increased with burn-off. This dynamic condition was followed by attainment of a stabilized temperature distribution. With establishment of thermal stability, plasticity was controllable and made it possible to obtain reproducible results in upset. Test welds were made with variables selected to obtain stable temperature distribution, and the interrelated effects of platen acceleration and upset on weld ductility were studied. Evaluation was made by a simple room-temperature beam-bend test. The bend-test fixture consisted of a $^{3}/_{16}$-in. ram and $^{1}/_{8}$-in. diam specimen supports $1^{1}/_{4}$ in. from center to center. A deflecting rate of 0.005 ipm was used.

For a given platen acceleration, weld-bend ductility increased and then decreased with increasing upset. Welds made in air with optimum upset conditions (0.150 to 0.200 in.) were capable of 30–65 deg bends. Poor bend ductility with little upset was attributed to retained oxidized material, porosity and redistribution of carbides to grain boundaries near the flashing interface. Poor ductility with excessive upset was associated with a severely transverse fibered weld structure. In such specimens, bends were parallel to the grain structure, an orientation normally associated with less ductility.

Arc-cast molybdenum welds made in argon and helium atmospheres had poorer bend ductility than those made in air. This loss of ductility was attributed to greater precipitation of carbides at the grain boundaries and to a coarser grain structure. These effects were caused by the decreased cooling rates resulting from the closed-chamber, inert-gas atmosphere surrounding the weld.

Purpose and Scope

The program reported herein was initiated to investigate the possibility of utilizing the flash-welding

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process in the fabrication of molybdenum hardware. To this end, development of a flash-welding schedule for 1/4- x 1-in. bar and evaluation of as-welded properties was accomplished. Since metal-moving techniques can be advantageously applied to molybdenum-base alloys, flash-weld specimens were also subjected to cold working to see if the joints could be worked into other shapes. Subsequent to working, the properties of the flash-welded specimens were determined over the expected temperature range of application.

Materials

The material used in this investigation consisted of four heats of 1/4 x 1 in. (nominal dimensions) arc-cast titanium-molybdenum alloy bar stock of commercial quality. Certified analyses received with the material are presented in Table 1. Structure of the as-received material is shown in Fig. 1.

Acceptance testing of the material consisted of a hardness check and determination of the ductile-brittle bend transition temperature; this was a routine test procedure at the time. By definition, the bend transition temperature is the minimum temperature at which the material will accept a 90 deg bend transverse to the rolling direction over a 1T radius ram without fracture. Bend specimens consisted of 3-in. long bar sections ground on all surfaces to remove a heavy layer of contamination and imperfections and radiused on all edges. These specimens were tested using the fixture shown in Fig. 2 with a 1/2-in. diam ram which was approximately equal to 1T radius bend. Loading was accomplished with a Baldwin testing machine using a cross head travel of 1 ipm. Specimens were heated to test temperature using a propane gas torch. Temperatures were measured with a chromel-alumel thermocouple and a potentiometer.

Results of acceptance testing are presented in Table 1. The moderate quantity of material available dictated a limited number of tests. A sufficient number of specimens were run to show:

1. The improvement in bend ductility possible by surface preparation, emphasizing the notch sensitivity of the material.
2. All four heats of material with a transition temperature of approximately 100° F.

The transition temperature was average, based on test records of previous heats of molybdenum, and the material was accepted.

Phase 1—Development of Flash-welding Technique

Procedure

After acceptance testing, 17 ft of material were abrasive sectioned into lengths of 6 to 7 in. The pieces were then ground on all surfaces. The finish ground cross section was 0.230 x 0.935 in. Tolerances were ±0.002 in., giving a cross-sectional area of 0.215 ± 1% sq in. The heat identity of each piece of material was retained.

Flash-welding development was conducted employing a 500 kva Taylor-Winfield flash-welding machine with a modified alligator type hydraulic clamping system. This unit provided an exponential type flashing curve following a constant velocity start. A two-channel Brush recording oscillograph was used to provide check readings of platen displacement and welding transformer primary current values during flash welding.

Quality of flash welds was determined by bend tests using the previously described technique and the fixture shown in Fig. 2. Bend test temperatures were determined using an Illinois Testing Laboratory, Inc. contact pyrometer, Type 4000 having a range of 0–300° F.

The amount of material available to the program did not permit extensive study of the effects of the several flash-welding variables. Rather, since Nippes' work emphasized the importance of upset, a judicious choice of other variables was made and the effects of variations in upset investigated.

Discussion

Test results of flash-welded speci-

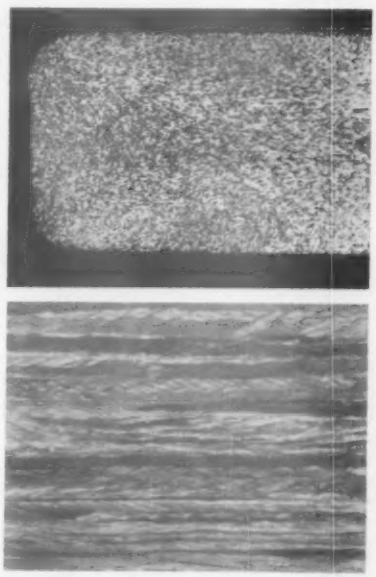

Fig. 1—Typical structure of as-received bar stock (top) transverse section X11 and (bottom) longitudinal section X500. Electrolytically polished and etched with NaOH + $K_3Fe(CN)_6$ + H_2O (reduced 50% on reproduction)

Table 1—Analyses And Properties of Molybdenum-titanium Bar Stock

Heat number[a]	Chemical analyses: Carbon, wt-%	Chemical analyses: Titanium, wt-%	Hardness: R_c	Hardness: R_b	Bend angle, deg: 80°F	100°F	150°F	200°F	300°F
TM1214	0.019	0.47	24	100–101	15[b, c]	65[c]	130	140	115
					75[c]	130			
					...	135			
TM1213	0.014	0.45	26	103–104	...	115			
TM1215	0.019	0.47	24–25	102–103	...	110			
TM1001	0.022	0.48	23–24	102–103	...	115			

[a] Universal Cyclops.
[b] Mill-rolled surface. All other specimens surface ground and edge radiused.
[c] Fractured at reported bend angle. All other specimens did not fail.

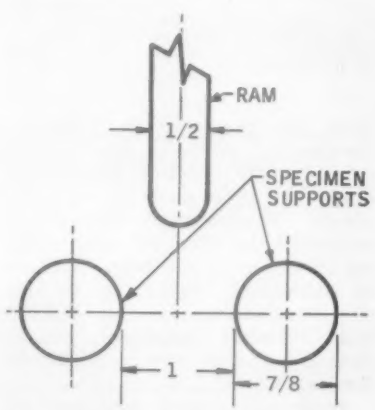

Fig. 2—Bend-testing fixture

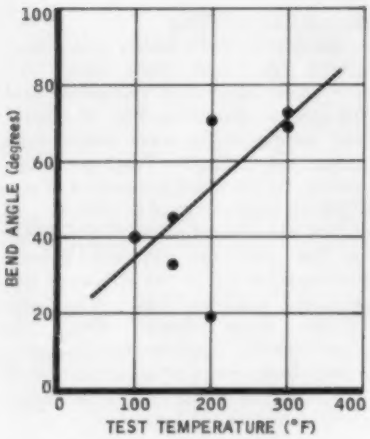

Fig. 3—Effect of test temperature on weld bend ductility ($^{7}/_{16}$ in. upset)

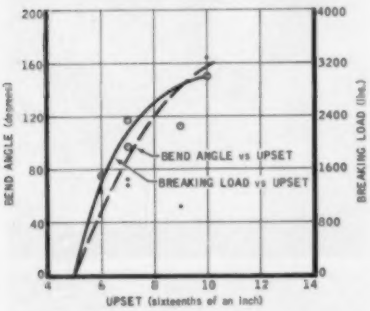

Fig. 4—Weld bend angle and breaking load as a function of upset (300° F test temperature)

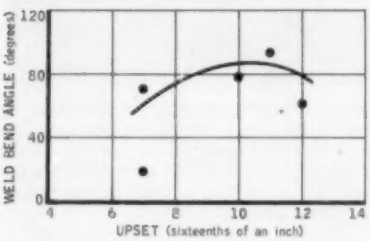

Fig. 5—Weld bend angle as a function of upset (200° F test temperature)

mens are presented in Table 2. Specimens 1 through 5 were welded using a single promising schedule to study the bend ductility of weldments. Specimens 6 through 12 evaluated the effect of various upset distances on the bend ductility of weldments. Specimens 13 and 14 were similar to the original weld schedule employed, except that heat input was progressively decreased.

Bend data were obtained at several temperatures for the welds

Table 2—Results of Tests on Flash-welded Specimens

Specimen	Heat number	Upset, in.	Test temperature, ° F	Breaking load, lb	Bend angle, deg
1	TM1215	$^{7}/_{16}$	100	1000	40
2	TM1001	$^{7}/_{16}$	150	1600	33
3	TM1001	$^{7}/_{16}$	150	1780	45
4	TM1001	$^{7}/_{16}$	300	1950	69
5	TM1001	$^{7}/_{16}$	300	2350	72.5
6	TM1215	$^{5}/_{16}$	300	0	0
7	TM1215	$^{3}/_{8}$	300	1500	63.5
8	TM1215	$^{9}/_{16}$	300	2250	52
9	TM1215	$^{5}/_{8}$	300	3000[a]	164
10	TM1213	$^{5}/_{8}$	200	....	78
11	TM1213	$^{11}/_{16}$	200	....	93
12	TM1213	$^{3}/_{4}$	200	....	61
13	TM1213	$^{7}/_{16}$	200	....	70.5
14	TM1213	$^{7}/_{16}$	200	....	19

[a] Specimen did not break.

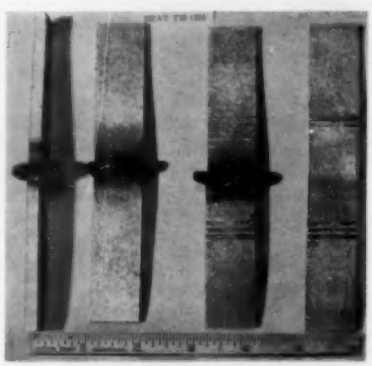

Fig. 6—0.5% titanium-molybdenum alloy flash-welded specimens before and after flash removal

made with $^{7}/_{16}$-in. upset. The information is presented in Fig. 3. The data confirm the improvement in bend ductility of molybdenum with increased test temperature through the brittle-ductile transition range. The 200° F test having abnormally low ductility was made at a reduced heat input; this prevented attainment of a proper temperature distribution in the material. The curve indicates an average bend angle of 35 deg at 100° F increasing to about 70 deg at 300° F.

The effect of upset on the bend angle and breaking load of weldments tested at 300° F is shown in Fig. 4. A trend of improved bend ductility may be noted as upset is increased from $^{5}/_{16}$ to $^{5}/_{8}$ in. A single weld made with $^{9}/_{16}$-in. upset has an unaccountably low bend angle. The plot of breaking load vs. upset gives a curve of the same trend with less scatter.

Additional tests conducted at a test temperature of 200° F and presented graphically in Fig. 5 confirm the relationship of bend ductility and upset. Maximum bend angles of 78–93 deg were attained at upsets of $^{5}/_{8}$ and $^{11}/_{16}$ in. However, increasing upset to a maximum of $^{3}/_{4}$-in. caused a loss in ductility.

Based on the foregoing experimental data, an upset distance of $^{11}/_{16}$-in. was selected for the final test specimens. Seven specimens were welded from heat TM 1215 material using the following schedule.

Final die opening, in.	$^{7}/_{16}$
Total burn-off, in.	$^{9}/_{16}$
Upset travel, in.	$^{11}/_{16}$
Flashing time, sec	5.5
Flashing current, phase shift, %	90
Upset time, cycles	20
Upset current, phase shift, %	60
Hold time, sec	3

Phase 2—Processing of Flash-welded Specimens

Final weld specimens were 0.230 x 0.935 x 6 in., the flash weld being at the midpoint of the 6-in. dimension. Figure 6 shows the appearance of the specimens both as-received and with flash removed. Parallel groves visible on two of the specimens were made by the clamping dies.

The flash was ground from all specimens, and the welds were radiographically inspected. One specimen was found to have a large crack traversing the weld, the result of an accidental impact in handling. The remaining five specimens were found to be sound.

One specimen was selected for

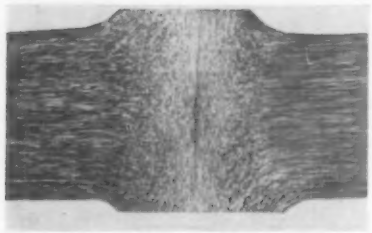

Fig. 7—Transverse macrostructure of flash weld ×10. Electrolytically polished and etched with NaOH + $K_3Fe(CN)_6$ + H_2O (reduced 50% on reproduction)

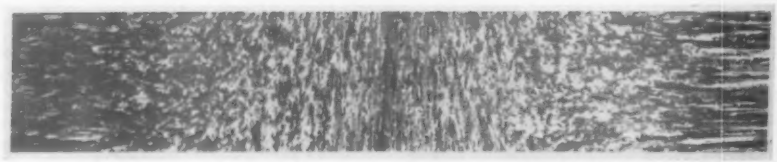

Fig. 8—Microstructure of flash weld—transverse section, X100 (reduced by 75% upon reproduction). Electrolytically polished and etched with NaOH + $K_3Fe(CN)_6$ + H_2O

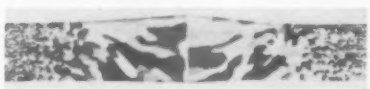

Fig. 9—Transverse macrostructure of fusion welded 0.5% titanium-molybdenum sheet X20. Electrolytically polished and etched with NaOH + $K_3Fe(CN)_6$ + H_2O (reduced 50% on reproduction)

metallographic evaluation. A weld cross section was obtained, mounted in Bakelite, electrolytically polished and then etched. This specimen was photographed and is presented in Figs. 7 and 8. Examination revealed a fine-grained, recrystallized and partially-worked structure. A moderate degree of transverse fibering, described by Nippes[5] as desirable, is visible. The weld hardness was 96–97 R_b compared with 102–103 R_b for the parent metal.

Comparison of the microstructure of the flash weld with Fig. 9, a typical gas-shielded tungsten-arc weld in sheet of the same molybdenum-base alloy reveals the finer grain size made possible by the flash-welding process. Average grain size of the flash weld is ASTM 6 and, of the fusion weld, approximately ASTM 2. The improved ductility of molybdenum obtained from grain refinement has been noted. In addition, some grain boundary contamination is normally visible in fusion welds at × 1000 magnification. Careful study of the flash-weld microstructure at magnifications up to × 1500 did not reveal grain boundary contaminants. This does not prove absence of such material, but it certainly proves that particle size was smaller and that the quantity of particles probably decreased. In particular, no carbide precipitation in the weld, such as reported in the Rensselaer program, was found. Favoring this result was the fact that the carbon content of commercial arc-cast molybdenum has been reduced approximately 50% since 1955 to a present normal level of 0.02%.

Tensile properties of both parent metal and as-welded specimens were determined at room temperature. Results are reported in Table 3. Based on ultimate tensile strength, the joint efficiency is 84%. This is excellent considering that a comparison is being made between a recrystallized weld structure and a parent metal whose strength has been increased by severe cold working.

Four flash-weld specimens were processed into 0.040-in. thick sheet material. In order to obtain a sufficient number of sheet tensile specimens to establish elevated temperature properties, specimens were rolled unidirectionally and parallel to the 1-in. dimension. Details of rolling schedules are not available.

The poorest and the best quality sheet panels are shown in the photograph of Fig. 10. These panels are approximately 4 x 6 in. Edge splits occurred to some degree in three panels. Chemical cleaning has etched the worked weld so that it is visible.

The panels were inspected by dye penetrant and found free from defects. Specimens were then selected for metallographic evaluation.

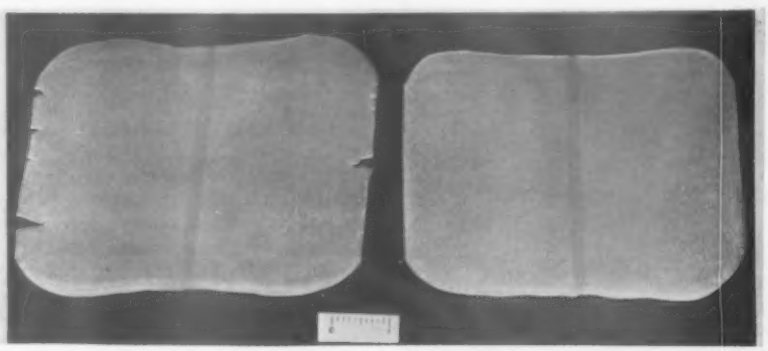

Fig. 10—Arc-cast 0.5% titanium-molybdenum alloy flash-welded specimens after hot rolling to 0.040-in. sheet from 0.230-in. bar

The metallurgical structure of the cold-worked flash weld is shown in Fig. 11. Working of the weld has resulted in a structure of small elongated grains. The additional working of the parent metal has created a more severely fibered structure than existed in the raw bar stock. This effect may be seen by comparing Fig. 12 with Fig. 1. A slight increase in parent metal hardness to 104–105 R_b was found. Weld hardness was 103–106 R_b.

Sheet panels were abrasive sectioned into strips and machined

Table 3—Room Temperature Tensile Properties of Parent Metal and Flash Welds

Specimen	Ultimate tensile stress, psi x 10^3	0.2% yield tensile strength, psi x 10^3	Elongation, %	Young's modulus, psi x 10^6	Failure location
Parent metal	118.0	...	24.0[a]	...	.....
Weld	98.4	88.3	7.0[a]	...	Edge of weld
Weld	102.2	91.9	6.0[b]	43.5	Center of weld

[a] In 1-in. gage length.
[b] In 1/4-in. gage length.

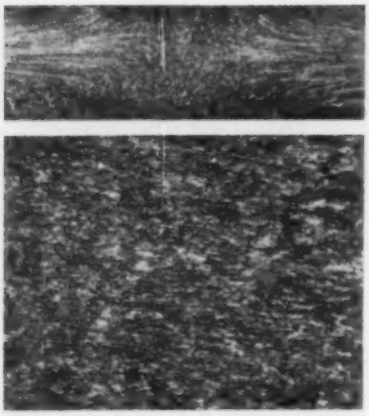

Fig. 11—Flash-weld microstructure of cold-worked specimen (top) transverse section X40 and (bottom) longitudinal section X500. Electrolytically polished and etched with NaOH + $K_3Fe(CN)_6$ + H_2O (reduced 50% on reproduction)

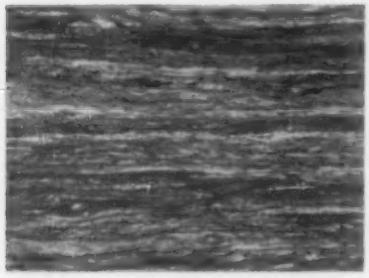

Fig. 12—Parent metal microstructure, longitudinal section, of cold-worked specimen X500. Electrolytically polished and etched with NaOH + $K_3FE(CN)_6$ + H_2O (reduced 50% on reproduction)

into tensile specimens according to Fig. 13. The profile of the reduced section was ground to finished dimensions. Tensile specimens were identified with test numbers, the original panel identity being retained. Measurements were made of the test length to obtain cross-sectional areas, and the specimens were coated with a commercial oxidation-resistant coating (Durak MG) for molybdenum. Metallographic examination of the control specimen revealed no microstructural change from the coating process. The coating thickness was 0.0015 to 0.002 in. over both parent metal and weld. Visually, the coating was a uniform black in appearance.

Phase 3—Testing of Sheet Tensile Specimens

Testing Program

Tensile specimens were tested on a machine[6] developed for elevated temperature testing. A single uncoated specimen was tested at room temperature. All other specimens were coated. Two specimens were tested at each of six test temperatures. Time at temperature was 2 min. Specimens were loaded at a strain rate of 0.001 in./in./sec up to the yield point and at 0.01 in./in./sec to rupture. Properties of the cold-worked weld specimens are presented in Table 4.

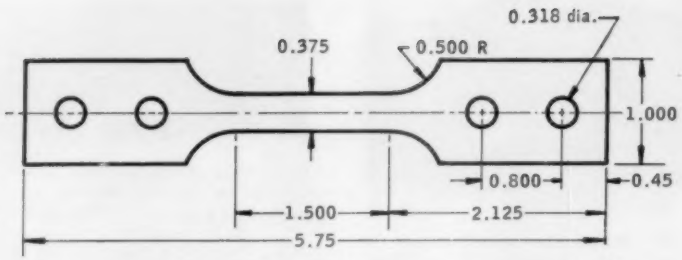

Fig. 13—Elevated temperature test specimen

Discussion

Cold-worked flash-weld specimens, which failed in the weld, were found to have ultimate and yield tensile strengths approaching parent metal properties obtained in other programs. Specimens tested at 2600° F and higher consistently failed in the parent metal. With the shift in failure location to parent metal at higher temperatures, elongation values increased. Metallographic studies of the tested specimens revealed that the shift in failure location coincided with recrystallization of the specimen.

There is no explanation for the parent metal failure of the uncoated specimen tested at room temperature. All specimens were carefully examined prior to and following testing so the existence of a defect cannot be assumed. The ultimate and yield strength properties of this specimen are unusually high, and the elongation is unusually low for the material. In part, this may be due to the fact that the specimen was neither cross rolled nor stress relieved. Typical room temperature properties of arc-cast 0.5% titanium-molybdenum alloy sheet in the cold-worked and stress-relieved condition are 90,000 to 115,000 psi ultimate strength and 80,000 to 105,000 psi yield strength as well as 10 to 15% elongation.

Conclusions

This program has shown that arc-cast 0.5% titanium-molybdenum alloy can be successfully joined by the flash-welding process. Furthermore, satisfactory joints can be made without protective atmospheres. As-welded joint properties compare favorably with parent metal properties considering the difference in metallurgical structures. Fabrication of components for use in the as-welded condition is therefore feasible.

It has been proved that flash-welded specimens can be successfully processed into sheet material. Joint tensile properties after such processing approach or equal parent metal properties in the useful temperature ranges for molybdenum-base alloys.

The possibility of using flash-welded rings or cylinders as preforms for the production of a considerable variety of hardware by the various metal-moving techniques has been demonstrated.

Acknowledgments

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Table 4—Tensile Properties of Cold-worked Flash-weld Specimens

Test temperature, °F	Ultimate tensile strength, psi x 10^3	0.2% yield tensile strength, psi x 10^3	Elongation in 1.5 in., %	Location of failure
80[a]	165.5[b]	156.0[b]	2.4[b]	Parent metal
2200	45.5	31.5	1.8	Weld
2600	24.2	15.9	4.3	Parent metal
2800	15.4	8.2	6.7	Parent metal
3000	13.6	8.4	8.5[b]	Parent metal
3200	10.0	5.6	6.7	Parent metal

[a] Uncoated specimen. All others oxidation-resistant coated.
[b] Single test value. All other data average of two values.

financial support of the Air Force which made this research possible.

The authors also wish to thank John Siergiej, former leader of the Metallurgical Development Group for his support of, and interest in, this program, and Edward D. Weisert, Assistant Section Supervisor, for his helpful criticism in the writing of this paper.

The services of Dresser Manufacturing Division in conducting the flash-welding portion of the program and of the Los Angeles Chromizing Corp. in oxidation-resistant coating the sheet test specimens are acknowledged.

Finally, the anthors' thanks to the staff of the Marquardt Materials and Process Laboratory for their assistance in conducting the testing phases of this program.

References

1. Platte, W. N., "Joining Molybdenum," WADC TR57-309, August, 1957.

2. Bechtold, J. H., "Recrystallization Applied to Control of the Mechanical Properties of Molybdenum," *Trans., Am. Soc. for Metals*, **46,** (1954).

3. Nippes, E. F., and Chang, W. H., "The Flash Welding of Commercial Molybdenum. Part I—Temperature Distribution During Parabolic Flashing of 1/2 in. Sintered and Wrought Molybdenum Rods," THE WELDING JOURNAL, **34,** (3), Research Suppl., 132-s to 140-s (1955).

4. Sohn, Jesse S., "Fusion Welding of Molybdenum Power Plant Components," American Society for Metals Publication, "Fabrication of Molybdenum," 103–118 (1959).

5. Nippes, E. F., and Chang, W. H., "The Flash Welding of Commercial Molybdenum. Part II—Production and Testing of Flash Welds of Molybdenum," THE WELDING JOURNAL, **34** (5), Research Suppl., 251-s to 264-s (1955).

6. Levy, A. V., and Bramer, S., "A Programming Universal Elevated Temperature Testing Machine," American Society for Metals Publication, "Elevated Temperature Testing" (1958).

EUROPEAN WELDING RESEARCH

By Gerard E. Claussen

SWITZERLAND

Steels and weld metals for service at +14 to −94° F were discussed in the June 1960 issue of the Swiss *Journal de la Soudure*. The failure of chlorine liquifier at −76° F was attributed to the embrittlement of the steel by cold working. For service at −40° F, an average notch impact value of 4 MKG/cm² and a minimum of 3.5 was specified in the transverse direction and for steel in the cold worked and aged condition, assuming no stress relief heat treatment after welding. Since weld metal is not usually cold worked, it is tested in the as-welded condition only for this specification. For service at −76° F or below, stress-relief heat treatment was considered indispensable.

CZECHOSLOVAKIA

The quarterly journal of the Czechoslovakian Welding Research Institute in Bratislava, *Zvaracsky Sbornik*, for the first quarter of 1960 contains the following articles:

A very brief summary of Rumanian tests on arc stability and on the theory of continuous welded rails.

The prefabrication in five sections of a 5900 ton freighter for Arctic service is described. The ship was built in Poland of killed open-hearth steel.

High-speed motion pictures of 7/32-in. covered electrodes deposited in argon and air showed that globules were large in argon independent of the carbon content of the core rod. In air there was a transition current to fine globules, which was lower for 6020 electrodes than for low-hydrogen electrodes. The results were believed to substantiate a reaction of carbons with oxygen to form hollow globules.

Crank shafts made by resistance butt welding were found to have the same fatigue characteristics, including failure through the oil hole, as forged crank shafts.

An electrode depositing 4.2 C, 5.2 Mn, 0.9 Si, 26 Cr, 0.8 V was satisfactory for facing gas generator valves operating in gas containing fly ash.

A 16 Cr–13 Ni steel containing 3% tungsten and 0.004% boron had high creep strength and scale resistance. Boron prevented the decomposition of the tungsten phase to sigma.

The use of the plasma arc torch for cutting aluminum, copper and steels is described.

Internal stresses up to 128,000 psi were found in the HAZ of welds in steel of 4130 type. These stresses accounted for delayed fracture of the martensite.

Designs of oxygen scarfing heads for scarfing billets in steel mills were discussed in detail.

The method of predicting HAZ structure and properties in welded steels from superposition of cooling curves on TTT diagrams is explained. TTT diagrams are given for steels containing 0.27 C, 1.5 Mn, 1.3 Si, 0.3 Cr, 0.2 Mo and 0.31 C, 0.63 Mn, 0.25 Si, 2.0 Cr, 0.5 Ni 0.3 Mn.

USSR

Avtomaticheskaya Svarka contains the following research articles in its June 1960 issue:

Maximum tensile residual stresses in an electroslag weld in mild steel plates 9 1/2-in. thick were found to be 42,000 psi parallel and transverse to the weld, and 26,000 psi in the thickness direction. These maxima were found at mid-thickness. Stresses at the surface were 3500 psi parallel to the weld, and a compressive stress of 18,000 psi transverse to the weld. During electroslag welding, distortion tends to close the gap ahead of the weld.

The resistance of welded joints in imperfectly titanium-stabilized austenitic stainless steel 3/16-in. thick (0.10 C, 17.36 Cr, 12.96 Ni, 0.43 Ti, 2.88 Mo) to intergranular corrosion was improved by attaching a water spray to the welding head. The water was directed on the hot weld one inch back of the arc. The welds were made at 220 amp, 26 v, 25 ipm with argon. Cooling curves showed extremely rapid cooling due to the water spray at 20 gallons per hour.

The quantity of SiF_3 fumes evolved from submerged-arc flux containing 5 to 7% CaF_2 (40 SiO_2, 36–49 MnO) during heating for 1 hr increased from zero at 750° F to 5% at 2200° F. During welding 0.15 to 0.25 g of SiF_4 was evolved per 100 g of slag. Rust added to the flux increased the hydrogen content of the weld.

DR. GERARD E. CLAUSSEN is associated with Arcrods Corp., Sparrows Point, Md.

Effects of Repeated Repair Welding of Two Aluminum Alloys

The extent of the heat-affected zone of welds in two aluminum alloys—one strain hardenable, the other heat treatable—is unaffected when repair welded up to six times

BY F. G. NELSON

Of utmost importance to the structural designer and fabricator are the questions of what happens to the mechanical properties across a groove weld and what changes occur in the width of the heat-affected zone in tempered materials when it is necessary to chip out unsound weldments and reweld one or more times.

The effects of repeated repair welding on the width of the heat-affected zone on either side of a groove weld have never been clearly defined. Until a few years ago, most welds were made using a process in which a preheat was considered necessary to obtain satisfactory joints, and the mechanical properties of a large portion of the material in the structure were affected by the welding procedure. The development of the inert-gas tungsten-arc and consumable-electrode methods, in which a preheat is not necessary, has made it possible to decrease the heat input during the welding process, so that the properties of the materials in only a narrow zone adjacent to the welds are affected. This consideration is applicable only to tempered materials, whether heat treated or cold worked since the heat of welding would not be expected to alter the properties of annealed material.

The investigation described in this paper was undertaken to determine any changes in the extent of the heat-affected zone and in the strength of the joint resulting from repeated repairs of welds in plates of two tempered aluminum alloys. Alloy 5456-H321 is representative of the high-strength alloys not heat-treatable, and alloy 6061-T6 is representative of the heat-treatable alloys. Both are covered by ASTM Specification B209-59T.

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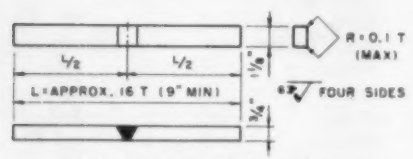
Paper to be presented at AWS 42nd Annual Meeting in New York, N. Y., Apr. 17-21, 1961.

Welding Procedure and Test Panels

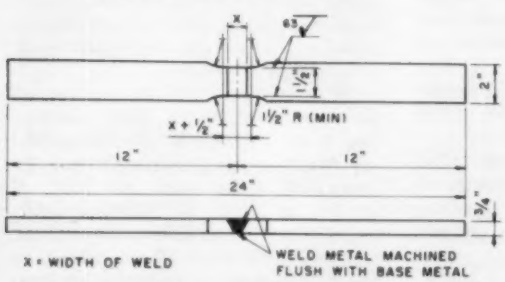
The semiautomatic inert-gas consumable-electrode process was used for welding the panels evaluated in this investigation. When this process is used, the welding torch is manually operated while the filler wire and shielding gas are automatically fed through the torch.

For each alloy, four panels consisting of two $^3/_4$-in. thick plates were groove welded in three passes. The edges of the plates were saw beveled so that a 60 deg included vee with an $^1/_8$-in. abutting land was obtained. The 5456-H321 plates were welded with 5456* filler wire and the 6061-T6 plates were welded with 5356 filler wire. The panels were prepared as follows:

1. Panel No. 1 was welded following commercial practices with two passes to fill the vee and one pass to complete the weld after back chipping the root. The panels were allowed to cool in still air before back chipping. There was no rewelding and no postweld heat treatment.
2. Panel No. 2 was completely welded as described above and then rewelded twice by repeating the following procedure. The face bead was chipped out to a depth of approximately one-half the thickness of the parent metal. This groove was filled in one pass. The panels received no subsequent thermal treatment.
3. Panel No. 3 was rewelded four times using the procedure for Panel No. 2.
4. Panel No. 4 was rewelded six times using the procedure for Panel No. 2.



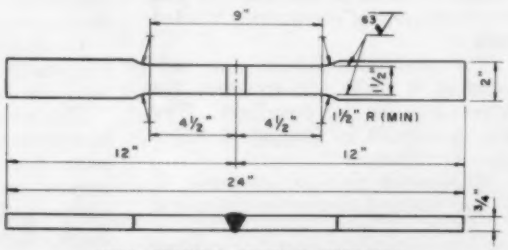
FREE-FACE-BEND SPECIMEN



REDUCED-SECTION TENSILE SPECIMEN

Fig. 1—Specimens from groove-welded plate

* Slightly modified and now designated as 5556.



FULL-SECTION TENSILE SPECIMEN

Except for the amperage, the welding conditions, viz., arc voltage, torch travel in in. per min, and the argon-gas flow in cu ft per hr were the same for all panels. The amperage used for the 5456-H321 panels was 415 while that for the 6061-T6 panels was 440. The chipping was controlled, insofar as that type of operation can be controlled, so that the resultant grooves obtained at successive steps were sufficiently similar that variations from this operation should be negligible.

In order to determine the quality of the welds, reduced-section tensile specimens were prepared and tested in accordance with Section IX of the ASME Boiler and Pressure Vessel Code; in addition, tensile tests were made of full-section specimens machined from each of the panels and free-bend tests were made on specimens machined from the 5456-H321 panels. The types of specimens used are shown in Fig. 1. The full-section tensile specimen is designed so that failure can occur in the 9-in. long reduced section either at or adjacent to the weld, whichever location is weaker. The free-bend-test specimen is one in which the elongation of the weld metal is determined by measuring the relative movement of gage marks placed on the weld before bending.

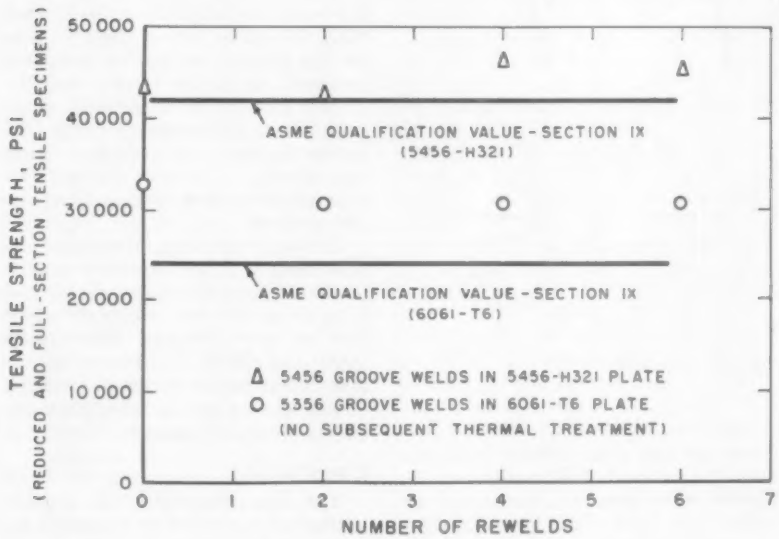


Fig. 2—Ultimate strength across groove welds in 3/4-in. thick plate

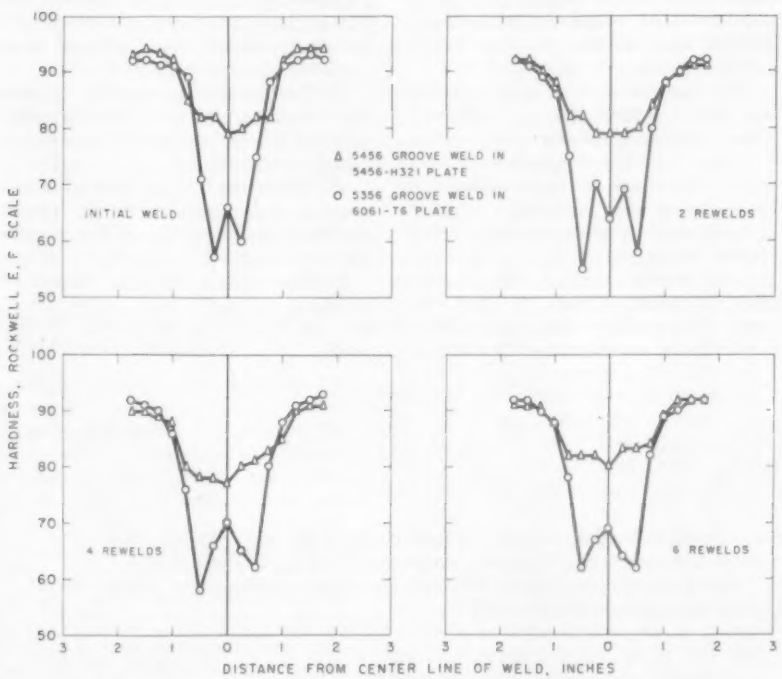

HARDNESS, ROCKWELL E, F SCALE
Δ 5456 GROOVE WELD IN 5456-H321 PLATE
O 5356 GROOVE WELD IN 6061-T6 PLATE
INITIAL WELD
2 REWELDS
4 REWELDS
6 REWELDS
DISTANCE FROM CENTER LINE OF WELD, INCHES

Fig. 3—Rockwell hardness vs. distance from centerline of weld

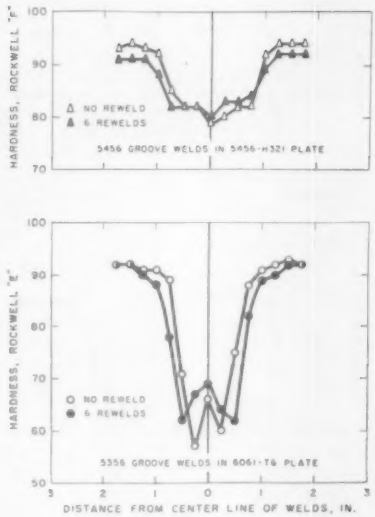

HARDNESS, ROCKWELL "F"
Δ NO REWELD
▲ 6 REWELDS
5456 GROOVE WELDS IN 5456-H321 PLATE
HARDNESS, ROCKWELL "E"
O NO REWELD
● 6 REWELDS
5356 GROOVE WELDS IN 6061-T6 PLATE
DISTANCE FROM CENTER LINE OF WELDS, IN.

Fig. 4—Rockwell hardness vs. distance from centerline of weld

Test Procedures

The tensile properties of the parent metal were determined using threaded-end cylindrical specimens machined and tested essentially in accordance with ASTM Method E8-57T. Hardness and tensile tests were made of each of the groove-welded panels to study changes in the width of the heat-affected zone accompanying the repeated repair welding.

Rockwell hardness tests were made in accordance with ASTM Tentative Method E-18-57T at $^1/_4$-in. intervals on each side of the weld until successive readings became constant.

Tensile specimens were machined from the parent metal parallel to the weld and alternately from each side of the weld at $^1/_2$-in. intervals, extending from the weld to well beyond the heat-affected zone, as indicated by the hardness tests. Tensile strengths, yield strengths and elongation were determined in

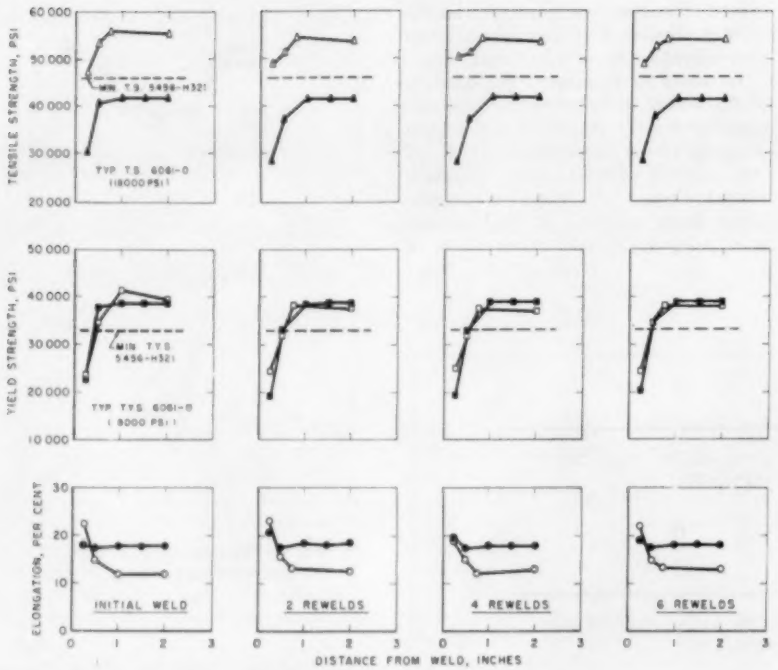


Fig. 5—Tensile properties of parent metal vs. distance from weld

accordance with ASTM Method E8-57T. The yield strengths were determined from load-strain diagrams obtained autographically and the elongations were measured over a gage length of 4D.

Results and Discussion

The tensile properties of the parent metal of each of the groove-welded panels met the applicable requirements as defined in ASTM Specification B209-59T, and the welded joints of each alloy met the qualification requirements of Section IX of the ASME Boiler Code. The data points shown in Fig. 2 represent the average strengths developed by reduced-section and full-section tensile specimens.

The Rockwell hardness surveys of the groove-welded panels of both alloys indicate, as shown in Fig. 3, that, irrespective of the number of times the panels are rewelded, there is little change in the width of the heat-affected zone. They indicate that the heat-affected zone does not extend more than $1^1/_2$ in. on either side of the weld. The small change in width is emphasized in Fig. 4, where the hardness curves obtained when the panels were rewelded six times are superimposed on those obtained from the panels that were not rewelded. The hardness test defines the width of the heat-affected zone quite clearly.

The results of the tensile tests also indicate that the heat-affected zone does not extend more than $1^1/_2$ in. from the centerline of the weld, regardless of the number of times the weld is repaired. It is of interest to note that the values for tensile strength of the 5456-H321 parent metal within the heat-affected zone, shown in Fig. 5, never drop below the qualification requirement of Section IX of the Boiler Code, which is equal to the specified minimum tensile strength of annealed material, viz., 42,000 psi (ASTM Specification B209). The values of yield strength at distances less than 1 in. from the weld fall below the specified minimum yield strength for 5456-H321 which is 33,000 psi (ASTM Specification B209) but not as low as the specified minimum tensile yield strength of annealed material. The values of tensile strength and yield strength of the parent metal within the heat-affected zone of the welded 6061-T6 plates never drop as low as the typical values for annealed material, which are tensile strength 18,000 psi and yield strength 8000 psi. The tensile strength never falls below the ultimate-strength qualification value for welds; for 6061-T6 this is 24,000 psi in Section IX of the Boiler Code.

The only evidence of an effect of rewelding is in the tensile strengths of 6061-T6 at distances of $^1/_2$ and 1 in. from the weld when there are two or more rewelds; there were 2000 and 3000 psi decreases, respectively, in the ultimate strength of the parent metal from that obtained from the panel not rewelded.

Conclusions

The data obtained in this investigation of the effect of repeated repair welding (up to six repair welds) on the mechanical properties and width of the heat-affected zone warrant certain conclusions concerning 5456-H321 and 6061-T6 (no subsequent thermal treatment) panels joined by the inert-gas consumable-electrode method.

1. The tensile properties across the welds are not significantly affected by the number of times the panels are rewelded.

2. The width of the heat-affected zone is not significantly increased by the number of times the panels are rewelded.

3. The effect of the heat of welding extends not more than $1^1/_2$ in. from the centerline of the weld.

Correction

See "Recent Progress in Development of Self-fluxing, Air Proof Brazing Alloys," by Nikolajs Bredz and Harry Schwartzbart in the March 1961, Research Supplement, p. 124-s. "$9H_2O$, 720" shown opposite Ba $(OH)_2H_2O$ in Table 2 should be "$-8H_2O$,720" with the following footnote: "Not fully decomposed in that water of hydration only is given off."

Some Metallurgical Aspects of CO_2-Shielded-Arc Welding

CO_2-shielded-arc welds in $^1/_8$- to 7-in. thick plate are reported to be sound with high resistance to both cold and hot cracking

BY M. D. RANDALL, P. J. RIEPPEL, S. L. HOYT AND A. F. CHOUINARD

During the last five years, CO_2-shielded-arc welding has become a joining process of major importance to fabricators of steel products. This process has certain technical advantages for welding structural steels and some other materials. The fact that acceptable welding of many items can be done with this process at lower cost than by any other process is a major factor in the rapid growth of its use.

In this process, the melting end of a continuously-fed wire electrode, the arc and the molten weld pool are blanketed by a stream of CO_2 gas. This stream of CO_2 sweeps air away from the arc and weld pool areas; it efficiently "shields" the arc and molten metal from the air. CO_2, however, is known to be oxidizing when in contact with molten steel. This gives rise to many questions concerning its use to protect molten steel from air. Some questions frequently asked are: How is severe oxidation avoided? What effects does CO_2 have on weld metal mechanical properties? What happens to alloying elements during welding? What materials can be welded with the process? Information on these questions and several others on metallurgical aspects of CO_2-shielded-arc welding are discussed in this paper.

Background Information on Shielded-arc Welding

Early in the development of electric-arc welding of steel, it was recognized that air had a damaging effect on weld-metal mechanical properties. Some of the first methods of improving weld quality was the use of various gases to shield the molten metal from the air. A great variety of gases and many types of equipment were tried to develop an improved arc-welding process. Among the gases tried were pure CO_2 which was investigated by Alexander.[1] His conclusion was that CO_2 did not improve weld metal; instead the welds produced had virtually no ductility. Lincoln[14] tried passing CO_2 through a hollow carbon electrode and obtained ductile welds in steel. One explanation for Lincoln's success was that the reaction between the carbon electrode and the CO_2 produced sufficient CO to minimize oxidation of the weld metal. Other investigators believed that CO was suitable for the shielding of welds but that CO_2 was not acceptable.

The advent of the successful coated, manual electrode in about 1930 slowed research on gas-shielded welding for many years. During that time, the arc-welding industry grew rapidly with continuous improvements in electrode coatings and fluxes. Several types of coated electrodes were evolved. During welding, the coatings of these electrodes decomposed to produce large quantities of gases and a residual slag. Evolved gas, slag and fluxes "shielded" the molten metal from the air. Welds with excellent mechanical properties were obtained. Weld metals contained 0.010% nitrogen by weight as compared to as much as 0.20% when bare wire electrodes were used. In addition, less porous welds were produced with the coated electrodes. Coated electrodes for mild steel, stainless steels, some nonferrous metals, hard-facing materials and low-alloy high-strength steels subsequently were developed.

During World War II a great deal of research was done on the development of coated electrodes for depositing low-alloy high-strength weld metals for joining armor plate. In the course of solving under-bead cracking and porosity problems associated with development of these electrodes, the gases generated by various typical coated electrodes were collected and analyzed by Mallett and Rieppel.[15] The results of these analyses are summarized in Fig. 1. The interesting part of these results, as they relate to this discussion, is the composition of gases generated by lime-type coated electrodes. Carbon monoxide and carbon dioxide were found to constitute from 80 to 90% of the gases generated by these electrodes. From 65 to 80% of the gases was carbon monoxide. These gases were the products of the thermal decomposition of carbonates in the coating during the welding operation. The predominant constituent was CO, because the gases generated by the coated electrodes were held in a confined collection apparatus and were not permitted to contact the air. If the gases had been permitted to contact the air as in normal welding, nearly all of the CO would have been oxidized back to CO_2 in the outer fringes of the welding arc.[10] The initial gaseous product of the disintegration of $CaCO_3$ is CO_2. The CO_2 is then dissociated to CO and O_2 in the high temperature part of the arc. There is some evidence indicating that some of the CO is also dissociated into C and O_2. This leaves a considerable amount of O_2 available to oxidize metallics or to recombine with the CO in the cooler region of the arc. Another reaction that would take place is the direct oxidation of iron and other metals on contact with CO_2 at high temperatures. For example, molten iron reacts with CO_2 producing iron oxide and CO in a reversible reaction:

$$Fe + CO_2 \rightleftarrows FeO + CO$$

On the basis of this information, shielding with CO_2 is not new,

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Paper to be presented at AWS 42nd Annual Meeting in New York, N. Y., Apr. 17-21, 1961.

CO_2 shielding combined with slags and fluxes of lime-type coated electrodes has been a major means of shielding arc welding from the air for many years. The metallurgical and mechanical properties of welds produced by lime-type coated electrodes or low-hydrogen electrodes are well known. It is through this general type of coating that successful electrodes for alloy high-strength steels, and stainless steels have been possible.

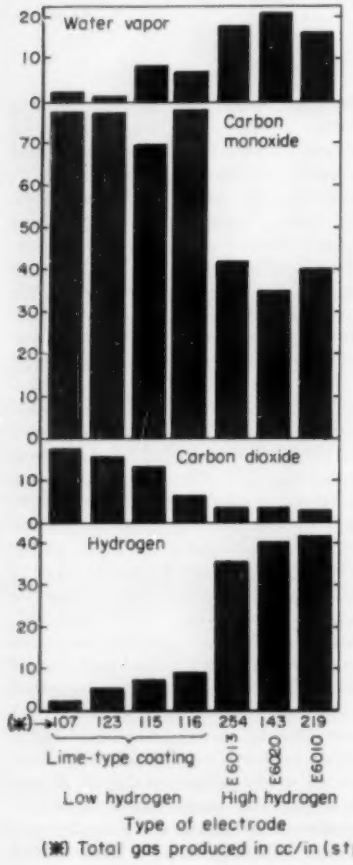

Fig. 1—Proportion of gases in atmospheres produced by various types of metal-arc coated electrodes

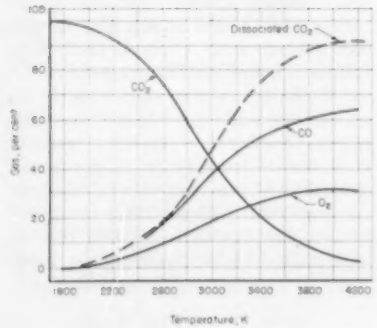

Fig. 2—Dissociation of CO_2 at equilibrium

Gaseous Products from CO_2-shielded-arc Welding

The information in Fig. 1 shows that a major part of the gaseous end products from lime-type low-hydrogen coatings is CO. (This is true only if these products are confined in a chamber and are not permitted to contact air.) This indicates that nearly all of the CO_2 generated from $CaCO_3$ (or other carbonates and coating ingredients) is reduced. At the same time, the CO_2 oxidizes metals by reactions such as the following:

$$Fe + CO_2 \rightleftarrows CO + FeO$$

Some of the oxide products become part of the slag. Also, the CO_2 in the immediate vicinity of the arc will dissociate according to the reversible reaction $2\ CO_2 \leftrightarrows CO + O_2$ with increasing temperature as shown in Fig. 2. This supplies oxygen for additional oxidation. These oxidizing reactions probably account for much of the usual loss of ferroalloys such as ferromanganese and ferrosilicon that are added to electrode coatings. The alloy additions to the coating and core wire of the electrode must be in excess of that which is oxidized in order to have enough silicon and manganese left to deoxidize and also alloy with the weld deposit.

With the information of Fig. 1 as background, two experiments were conducted to study the oxidizing affect of CO_2 when used alone as a shield in the absence of coatings, slags or flux. In one experiment, 100% CO_2 was flowed through a small hole down the center of a $^3/_{16}$-in. diam mild steel electrode. The rate of flow was set to approximate the amount of gas generated by a $^3/_{16}$-in. diam low-hydrogen type coated electrode. Since the CO_2 was flowing through the hole in the center of the electrode, the gas had to pass out through the arc. The welding was done in a small closed chamber purged with CO_2 so that none of the end products could come in contact with air. Samples of end product gases were analyzed. It was found that 57% of the CO_2 was converted to CO. The weld deposit was very porous, indicating that there was not enough manganese and silicon left to deoxidize the weld metal after 57% of CO_2 had been reduced to CO. Had the wire of the hollow electrode contained an adequate amount of manganese and silicon, the weld deposit would probably have been sound.

In the other experiment, welding was done with automatic CO_2-shielded consumable-electrode welding using standard commercial equipment, shielding nozzle and various filler wires. An inverted cup about 3 in. in diam was arranged concentric with the shielding nozzle as shown by Fig. 3. A seal between the lower end of the cup and the workpieces was made

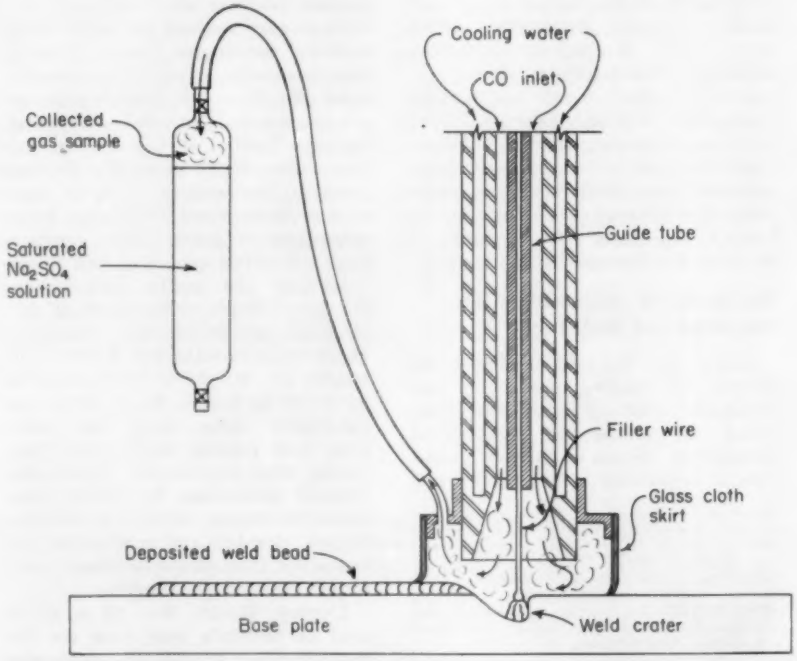

Fig. 3—Sketch of gas collection setup for CO_2-shielded welding process

Table 1—End Product Gases from CO_2-shielded Consumable-electrode Welding Process

Base plate type	Electrode	CO_2-shielding gas flow, cfh	Gases evolved, vol., % CO_2	CO
AISI 1020	Mild steel, 0.15-C, 0.93-Mn, 0.38-Si, weight per cent	30	66	34
	Flux-cored electrode A	30	84	16
	Flux-cored electrode B	30	82	18
	Flux-cored electrode C	30	83	17
	Flux-cored electrode D	30	83	17
Type 304 stainless steel	Type 304 stainless steel	30	78	22
AISI 4140	AISI 4340	30	58	42

with glass cloth. This arrangement made it possible to do normal CO_2-shielded automatic welding, but it did not permit air to contact the gaseous end products. Samples of the gases were taken after a few seconds of normal welding; this allowed the original gases in the cup to be flushed out. Test runs were made with commercial solid wires for welding mild steel, low-alloy high-strength steels and stainless steels. Also, flux-cored electrodes for welding mild and low-alloy steel were studied. The base plates were mild steel, low-alloy high-strength steel and stainless steel generally similar in composition to the wires. The weld deposits were sound and free from any gross porosity.

The analyses of the gas samples collected are shown in Table 1. The results of this experiment, those from the hollow electrode experiment, and the data in Fig.1 show that considerable quantities of CO_2 are converted to CO while metals in the arc region are oxidized. It can be seen from the data in Table 1 that the quantity of CO gas evolved increases as the carbon content increases. The carbon-oxygen reaction, $2C + O_2 \rightleftarrows 2CO$, probably is responsible for this relation. The oxygen, dissociated from the CO_2, combines with carbon of the molten weld pool to produce CO gas. When the CO is permitted to come in contact with air in the outer regions of the gas shield it is oxidized back to CO_2. Keller[10] showed that the CO content of the atmosphere 1 in. from a CO_2-shielded consumable-electrode welding arc was 0.1% by volume and 0.01% by volume 7 in. from the arc.

Oxidation Losses in CO_2-shielded-arc Welding

One reason for the failure of early investigators to recognize the adaptability of CO_2 as a weld shielding gas was the difficulty experienced in producing sound weld metal. In most instances, these investigators used steel filler wires which did not contain sufficient deoxidizing elements to successfully deoxidize the weld pool and allow for oxidation losses in the arc and weld pool from the oxidizing shielding gas.

To appreciate the role of deoxidizers in welding electrodes, it is necessary to understand the basic principles of deoxidation. The purpose of deoxidation in the weld pool is to obtain weld metal free of porosity. Actually, this amounts to reducing the quantity of oxygen in the molten weld pool. Without adequate deoxidation, the oxygen in the molten steel is free to combine with carbon in the reaction $2C + O_2 \rightleftarrows 2CO$ to produce a gaseous product, carbon monoxide. If the weld pool freezes before the gas can reach the weld surface, the gas is entrapped producing porosity. So, a successful deoxidizer must combine with the oxygen in the molten steel in preference to the carbon to form an insoluble compound. This compound precipitates and floats to the top of the weld pool to produce weld slag. Various elements are used in steelmaking and in welding electrodes for deoxidizers. The relative deoxidizing power of these elements used are shown in Fig. 4. Silicon and manganese have been and still are the most widely used deoxidizers for welding

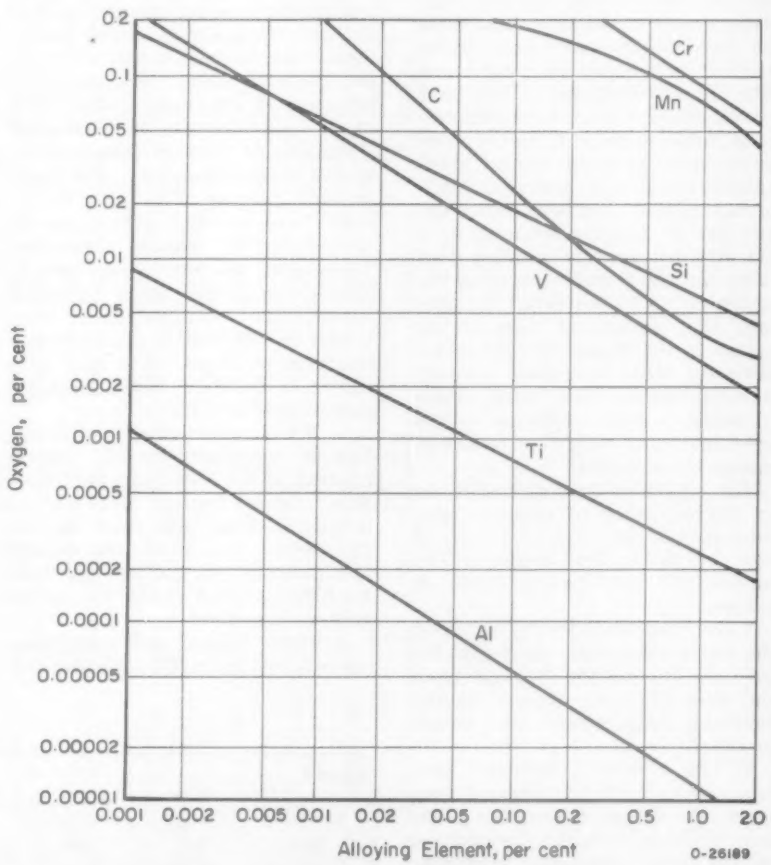

Fig. 4—Relative deoxidizing power of some of the elements (from "Basic Open Hearth Steelmaking" published by AIME)

Table 2—Examples of Alloying Element Losses for Various Base Plate and Filler Metal Compositions

Test	Chemical composition, by weight, %						
	C	Mn	Si	Cr	Ni	Mo	Ti
Base-metal	0.19	0.53	0.24	..	..	..	..
Electrode, Cb-10 Г С	0.15	0.82	0.62	..	..	..	..
Weld metal	0.12	0.27	0.16	..	..	..	..
Electrode, Cb-20X Г СА	0.20	0.95	1.20	0.99	..	..	..
Weld metal	0.14	0.57	0.51	0.41	..	..	...
Base metal, 30X Г СА	0.36	1.08	0.95	0.92	..	..	..
Electrode, Cb-1A	0.10	0.43	0.03	..	..	..	..
Weld metal	0.21	0.64	0.57	0.55	..	..	..
Electrode, Cb-20X Г СА	0.20	0.95	1.20	0.99	..	..	..
Weld metal	0.22	0.81	0.87	0.89	..	..	..
Base metal, 1X18H9T	0.09	0.52	0.72	18.97	..	..	0.50
Electrode, 1X18H9T	0.10	0.50	0.48	19.05	..	..	0.61
Weld metal	0.10	0.40	0.45	17.73	..	..	0.24

electrodes. However, it can be seen from Fig. 4 that aluminum and titanium are more effective deoxidizers and have been used in electrodes.

Considerable research has been done abroad as well as in this country to determine the oxidation losses in welding arcs. Novozhilov[18] and later Golub and Suslov[5,25] made extensive investigations into the loss of various elements in welding carbon and stainless steels with CO_2-shielding gas. They used a wide range of filler wire compositions with various types of base plates such as plain carbon steel, stainless steel and low-alloy high-strength steel. Table 2 shows the recovery of alloying elements in a CO_2-shielded arc for varying base plate and filler metals used as determined by Novozhilov. In general, the percent of element recovery in the deposited weld metal increased with increasing alloying content, because the initial losses of elements from oxidation in the arc column and weld pool remained reasonably constant.

The effects of welding conditions on the oxidation of elements also were studied by Novozhilov[18] and later by Golub and Suslov.[5] The results of their work were as follows:

1. Increasing arc length increased the oxidation losses, probably bebecause the molten droplets from the electrode were exposed to the oxidizing atmosphere for longer periods of time.

2. The effects of increased current and reduced travel speed were to produce deeper penetration of the base plate so that the composition of the base plate had a greater influence on the chemical composition of the deposited weld metal.

Transfer Efficiency of Elements Across Arcs

Considerable research has been directed toward determining the transfer efficiency of elements across an arc in CO_2 and in argon-oxygen mixtures. In these tests, welds were deposited in succeeding layers and the drillings for chemical analyses were removed at points where there was no base metal dilution, i.e., all weld metal. Schumacher[21] investigated the transfer efficiencies of various elements in flux-cored electrodes of various compositions with CO_2-shielding gas. For comparison purposes, he also determined the transfer efficiencies of several coated, manual electrodes. These data are shown in Table 3. Similar tests were made by other investigators with solid-wire electrodes in CO_2 and in argon-oxygen mixtures. These data also are shown in Table 3. The results are summarized as follows:

1. The transfer efficiency of carbon is dependent on the carbon content of the base plate and filler wire; for low carbon (0.05–0.12%) austenitic base and filler metals, the carbon content in the deposit is higher than in the welding wire; for higher carbon steels, the carbon content is reduced.

2. Both silicon and manganese are oxidized in the CO_2-shielded arc; the percent loss decreases with increasing silicon and/or manganese content; however, in general, a greater quantity of one of these elements produces a lower loss of the other element.

3. There is practically no loss of chromium or nickel.

4. With titanium contents up to 1% over half the titanium is lost by oxidation; with higher titanium contents, the loss is lower and generally does not exceed 30%.

5. The transfer efficiencies of the various electrodes and shielding gases varied from the highest to the lowest as follows: (*a*) solid wire in argon-oxygen mixture; (*b*) coated-manual electrode; (*c*) solid wire in CO_2; and (*d*) flux-cored electrode in CO_2.

As far as losses by oxidation are concerned, Novozhilov[18] concluded that welding in a CO_2-shielding gas is about equivalent to welding in an argon—plus 15% oxygen mixture. Since alloy losses can be anticipated and the electrode compositions adjusted for these losses, the consumable-electrode, CO_2-shielded welding process ean be used effectively to join a wide variety of types of steel.

Mechanical Properties of CO_2-shielded Welds

The mechanical properties of welds deposited by the CO_2-shielded consumable-electrode welding process are similar to welds deposited by other gas or flux-shielded welding processes. Tests were made at Battelle to compare the mechanical properties of welds deposited in CO_2 and in argon-shielding gases. A commercially available, $^3/_{32}$-in. diam filler wire was used for these tests. The chemical composition of the filler wire was as follows: C, 0.15%; Mn, 0.93%; Si, 0.38%; P, 0.018%; and S, 0.023% by weight. All weld metal 0.505-in. diam tension specimens and Charpy keyhole-notched impact specimens were tested from welds deposited with this electrode in both CO_2 and in argon-shielding gases. The results are in Table 4.

These results are typical for mild or structural grade steel weld de-

Table 4

Shielding gas	Yield strength, psi	Ultimate strength, psi	Elongation in 2 in., %	Reduction of area, %	Notch toughness, ft-lb	
					at 75° F	at 0° F
CO_2	54,300	68,100	32	64	40	39
Argon	52,250	67,400	36	65	47	39

Table 3—Recovery of Alloying Elements of Various Arc Welding Electrodes in Gas Shields of CO_2 and Argon-oxygen Mixtures

Test	Type of electrode	Shielding gas	Chemical composition: C		Mn		Si		Cr		Mo		Ni		Ti	
			Specimen content, %	Coefficient transfer	Specimen content, %	Coefficient transfer	Specimen content, %	Coefficient transfer	Specimen content, %	Coefficient transfer	Specimen content, %	Coefficient transfer	Specimen content, %	Coefficient transfer	Specimen content, %	Coefficient transfer
Flux-cored electrode A,[21] weld metal	Flux-cored	CO_2	0.14	...	3.50	...	1.85	...	...	...	...	...	...	...	...	...
			0.10	0.71	1.30	0.37	0.85	0.46	...	...	...	...	...	...	...	..
Flux-cored electrode B,[21] weld metal	Flux-cored	CO_2	0.10	...	2.30	...	1.00	...	...	...	...	...	...	...	...	...
			0.08	0.80	0.85	0.37	0.40	0.40	...	...	...	...	...	...	...	...
Flux-cored electrode C,[21] weld metal	Flux-cored	CO_2	0.11	...	3.30	...	0.90	...	...	...	0.50	...	...	...	...	...
			0.05	0.45	1.25	0.38	0.30	0.33	...	...	0.50	1.00	...	...	...	...
Flux-cored electrode D,[21] weld metal	Flux-cored	CO_2	0.19	...	1.60	...	1.40	...	1.90	...	0.75	...	...	...	...	...
			0.15	0.79	0.80	0.50	0.90	0.64	1.55	0.82	0.60	0.80	...	...	...	...
Coated, manual electrode,[21] weld metal	E-8016	None	0.16	...	1.15	...	0.75	...	...	...	...	...	2.03	...	...	...
			0.10	0.62	0.75	0.65	0.50	0.67	...	...	...	...	2.00	0.98	...	...
Coated, manual electrode,[21] weld metal	E-9016	None	0.15	...	1.00	...	0.75	...	...	...	0.50	...	...	...	...	...
			0.10	0.67	0.70	0.70	0.65	0.87	...	...	0.50	1.00	...	...	...	...
Coated, manual electrode,[21] weld metal	E-7018	None	0.10	...	1.40	...	1.30	...	...	...	...	...	...	...	...	...
			0.08	0.80	0.85	0.61	0.55	0.42	...	...	...	...	...	...	...	...
Electrode Cb-10 C,[18] weld metal	Solid wire	CO_2	0.15	...	0.82	...	0.62	...	...	...	...	...	...	...	...	...
			0.09	0.60	0.34	0.42	0.20	0.32	...	...	...	...	...	...	...	...
Electrode Cb-20X CA,[18] weld metal	Solid wire	CO_2	0.20	...	0.95	...	1.20	...	0.99	...	...	...	...	...	...	...
			0.12	0.60	0.66	0.70	0.86	0.72	0.91	0.92	...	...	...	...	...	...
Electrode 1X18H9T,[18] weld metal	Solid wire	CO_2	0.10	...	0.50	...	0.48	...	19.05	...	...	...	...	...	0.61	...
			0.09	0.90	0.28	0.56	0.43	0.89	17.22	0.90	...	...	...	...	0.16	0.26
Mild steel wire,[20] weld metal	Solid wire	CO_2	0.11	...	1.09	...	0.47	...	...	...	...	...	...	...	...	...
			0.09	0.82	0.68	0.62	0.28	0.59	...	...	...	...	...	...	...	...
Mild steel wire,[20] weld metal	Solid wire	A + 1 O_2	0.11	...	1.09	...	0.47	...	...	...	...	...	...	...	...	...
			0.08	0.73	0.93	0.85	0.39	0.83	...	...	...	...	...	...	...	...
308 Stainless steel wire,[20] weld metal	Solid wire	CO_2	0.043	...	1.77	...	0.40	...	21.20	...	...	...	9.80	...	...	...
			0.099	2.3	1.58	0.89	0.34	0.84	20.50	0.97	...	...	10.00	1.00	...	...
308 Stainless steel wire,[20] weld metal	Solid wire	A + 1 O_2	0.043	...	1.77	...	0.40	...	-21.20	...	...	...	9.80	...	...	...
			0.032	0.74	0.74	0.93	0.38	0.95	21.50	1.00	...	...	9.82	1.00	...	...

posits and agree, generally, with the results of other investigators for this type of steel. The mechanical properties of welds in stainless steels or in low-alloy steels deposited by the CO_2-shielded consumable-electrode process are similar and in some cases, better than those of welds deposited by either submerged-melt or coated-manual electrodes. One reason advanced for the improvement in mechanical properties of CO_2-shielded welds over submerged-melt welds is that there are fewer inclusions than in submerged-melt welds. Also, the inclusion, usually globular complex silicates, seem to be smaller in size. To explain the improvement in rupture and creep strength of heat-resistant alloys welded by the CO_2-shielded process over those welded by the submerged-melt process, Kasatkin, *et al.*,[7] examined the inclusions of each weld. They found that the CO_2-shielded arc welds contained only $^1/_4$ as many inclusions as did the submerged-melt welds.

Another reported advantage of CO_2-shielded arc welds is that they have greater hot-cracking resistance than either submerged-melt, inert-gas or coated-manual electrode deposits. Work reported by Medovar and Rublevskiy[17] showed that the hot-cracking resistance of CO_2-shielded welds in single phase austenitic steels was greatly improved over the resistance of argon-shielded welds in the same steel. Similar results were reported by Sekiguchi and Masumoto[22] on welds in high-strength steels made by the CO_2-O_2-shielded welding process. These investigators attribute this increased resistance to hot cracking to a reduction of hydrogen, phosphorus and possibly sulfur in the deposited weld by oxidation during welding.

Another important advantage of CO_2-shielded welds is their extremely low-hydrogen content. Sekiguchi, *et al.*,[22] studied the hydrogen evolved from welds deposited by the CO_2-O_2-shielded process, the inert-gas, metal-arc, submerged-melt process and by the low-hydrogen, coated manual electrode process and found that the hydrogen evolved from these welds was as shown below.

They attribute this low-hydrogen content of the CO_2-O_2-shielded weld to the fact that no fluxes or electrode coatings are present to absorb moisture. Other investigators have had similar results and believe that the hydrogen is removed by the water vapor reaction:

$$FeO + 2H \rightleftarrows Fe + H_2O$$

The former explanation appears to be more plausible.

Table 5

Process	Hydrogen evolved, ml per 100 g
CO_2-O_2	0.15
Argon, metal arc	0.7
Submerged melt	2.7
Low hydrogen, manual electrode	3.6
Ilmenite-type coated electrode	21.9

Summary

The past five years have shown a tremendous interest in the application of carbon dioxide gas to the shielding of electric-arc welds. Considerable research has been done in this country on the process; however, considerably more fundamental research has been reported in the Russian and European literature than in U. S. literature. A selected bibliography on the subject of CO_2-shielded welding is attached. The significant results of this research are summarized as follows:

1. Sound welds with good mechanical properties can be deposited by the CO_2-shielded arc-welding process in a variety of steels such as plain carbon, austenitic stainless, heat-resistant and low-alloy, high-strength steels provided suitable filler wires with compositions adjusted for oxidation losses are available.

2. CO_2-shielded-arc welds are reported to have high resistance to both hot and cold cracking. It has been hypothesized that this is the result of oxidation of H_2, S and P.

3. The process is adaptable to the joining of plates $^1/_8$ to 6 or 7 in. thick, with high deposition rates, good weld appearance and low inclusion count.

The CO_2-shielded arc-welding process with its many advantages, promises to be one of the most versatile of the arc-welding processes.

Bibilography

1. Alexander, P., *Gen. Elec. Rev.*, **XXIX** (3), 1926.

2. Carey, J. D., and Mann, R. D., "Mild-Steel Electrodes for Gas-metal-arc Welding in Carbon Dioxide," THE WELDING JOURNAL, **35** (6), 556–559 (1956).

3. Chouinard, A. F., and Monroe, R. P., "A New CO_2 Welding Process," *Ibid.*, **36** (11), 1069–1073 (1957).

4. Gilde, W., "The Thermodynamics of Welding in an Atmosphere of Carbon Dioxide," *Schweisstechnik*, **6** (6), 164–167 (1956).

5. Golub, L. V., and Suslov, V. N., "Repairing Defects in Steel Castings with Carbon Dioxide-Shielded Arc Welding," *Sbornik Novoyev Tekhnologii Svarku*, 191–212.

6. Hebold, G., "Review of International Literature on CO_2 Welding," *Schweisstechnik*, **7** (9 and 11), 334–339 and 407–410 (1957).

7. Kasatkin, B. S., Kakhovskiy, N. I., and Vakhnin, T. N., "Automatic Carbon Dioxide-Shielded Arc Welding of Heat-Resistant Steel 15×Ma," *Automat. Svarka*, (3), 28–38 (1957).

8. Kasatkin, B. S., Kakhovskiy, N. I., and Vakhnin, T. N., "Automatic Carbon Dioxide-Shielded Arc Welding of Low-Alloy High-Tensile Steels," *Ibid.*, (3), 39–43 (1957).

9. Kasatkin, B. S., Kakhovskiy, N. I., and Vakhnin, T. N., "The Problem of Carbon Dioxide-Shielded Arc Welding of Alloy Steels," *Ibid.*, (5), 19–21 (1956).

10. Keller, R. J., and Koss, J., "The Carbon Dioxide-Shielded Metal-Arc Welding Processes," THE WELDING JOURNAL, **35** (2), 145–151 (1956).

11. Keller, R. J., "Carbon-Dioxide-Shielded Metal-Arc Welding of Carbon-Steel Plate," *Ibid.*, **38** (1), Research Suppl., 27-s to 38-s (1959).

12. Kobayashi, H., "CO_2-Shielded Metal Arc Welding," *Welding Rev.*, **5** (8), 542–544 (1957).

13. Lioubavski, K. V., and Novozhilov, N. M., "Welding with Consumable Electrodes in an Atmosphere of Active Protective Gases," *Avtogennoe Delo*, **24** (1), 4–8 (1958).

14. Lincoln, J. C., U. S. Patent No. 1,589,017 (1926).

15. Mallett, M. W., and Rieppel, P. J., "Arc Atmospheres and Underbead Cracking," THE WELDING JOURNAL, **25** (11), Research Suppl., 748-s to 759-s (1946).

16. Medovar, B. I., Dudko, D. A., and Rublevskiy, I. N., "Oxidation of Alloying Elements in Carbon Dioxide-Shielded Arc Welding with Austenitic Electrode Wire," *Avtomat. Svarka* (3), 64–69 (1957).

17. Medovar, B. I., and Rublevskiy, I. N., "Problems in Carbon Dioxide-Shielded Arc Welding of Chromium-Nickel Austenitic Steels and Heat-Resistant Alloys," *Ibid.*, (3), 70–84 (1957).

18. Novozhilov, N. M., "Metallurgical Aspects of Gas-Shielded Arc Welding," *Sbornik Novoye v tekhnologii svarku*, 158–190 (1955).

19. Potap'Yevskiy, A. G., "Carbon Dioxide-Shielded Arc Welding of Stainless IN8H9T-Type Stainless Steel 3 mm Thick," *Avtomat. Svarka* (5), 13–18 (1956).

20. Rothschild, G. R., "Carbon Dioxide-Shielded Consumable-Electrode Arc Welding," THE WELDING JOURNAL, **35** (1), 19–29 (1956).

21. Schumacher, W. G., Private communication of data obtained at National Cylinder Gas Div., Chemetron Corp., Chicago, Ill.

22. Sekiguchi, H., and Masumoto, I, "Low Crack Sensitivity of Steel Joint by CO_2-O_2 Arc Welding," THE WELDING JOURNAL, **37** (7), Research Suppl., 326-s to 336-s (1958).

23. Sekiguchi, H., "Recent Researches on the Carbon Dioxide Shielded-Arc-Welding Processes," *Japanese Welding Soc.*, **26** (4), 237–248 (1957).

24. Sekiguchi, H., and Masumoto, I., "On the Carbon Dioxide Sekiguchi Filler Wire-Arc Welding Process," *Ibid.*, **25** (11), 608–611 (1956). Report No. 2, **25** (12), 674–681 (1956); Report No. 3, **26** (1), 14–22 (1957); Report No. 4, **26** (9), 573–578 (1957); Report No. 6, **27** (1), 31–38 (1958).

25. Suslov, V. N., "Selection of Electrode Wire for Carbon Dioxide-Shielded Arc Welding of Low-Carbon Steel," *Sbornik Novoye v tekhnologii svarku*, 213–220.

25. Tuthill, R. W., "Mild Steel Welding in Carbon Dioxide Atmospheres," *Welding and Metal Fabrication*, **23** (9), 335–338 (1955).

27. Tuthill, R. W., "Moisture and Its Effects in Carbon Dioxide Welding of Steel," THE WELDING JOURNAL, **35** (4), 330–333 (1956).

Quenched and Tempered Steels in Ship Structure

HY-80 steel welding study stresses use of low-alloy, ferritic electrodes and need for proper weld design and quality control

BY THOMAS J. DAWSON

Introduction

The catastrophic failures of ships during World War II traced to the notch sensitivity of the material from which they were constructed prompted research the world over in search of more notch tough materials for construction. The American Bureau of Shipping and U. S. Coast Guard made extensive investigations of plating for ship structure resulting in a change of the specifications for American Bureau of Shipping structural steel for hulls to improve notch-toughness characteristics. The Navy was faced with a bigger problem due to the shock characteristics necessary for military use.

Leaders in the military field included personnel of the Naval Research Laboratories where W. S. Pellini and P. P. Puzak developed a criterion for evaluating the properties of metals based on their performance during explosion bulge test and drop weight test[1]. Results of these investigations pointed to the quenched and tempered low-alloy steel materials as being the material possessing the necessary combination of strength and notch toughness to withstand the massive structural deformation under possible explosive attacks. This resulted in the development of an alloy defined as HY-80 (MIL-S-16216), which has its commercial counterpart in "T-1" steel.

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The material was more weldable and still possessed adequate strength and notch toughness to be highly resistant to brittle fracture even if severely deformed at temperatures as low as −120° F. The uses of this material, however, in rigid structures of high restraint have presented welding problems not experienced previously with other materials considered as readily weldable.

Background of Material Development

After the cessation of the hostilities of World War II, concentrated effort the world over was placed on the development of more notch-tough materials for use in construction. This was of special interest to the marine industry due to their experiences with the World War II ships mass produced by welding to monolithic designs.

Early research indicated that quenched and tempered low-alloy steels offered the greatest promise in this field. Considerable experience had been obtained by naval shipyards and commercial shipyards with the use of a Navy material known as STS steel. Test results on low-carbon heats of this material prompted a modification of this alloy to a low-carbon, nickel, chromium, molybdenum steel which, when quenched and tempered, develops a yield strength of 80,000 psi in thicknesses up to 1¼ in. with notch-toughness values based on Charpy V notch test at 50 ft-lb. at − 120° F. It was given the grade "HY-80" under Military Specification S-16216. This material was used for light armor applications to surface ships such as carrier flight decks with good success and was welded with MIL-S-260 electrodes.

The interest in the application of atomic energy to submarine construction made it evident that the diameter of the hull would have to be increased in order to successfully encase the necessary equipment to utilize this promising power. Further research on the HY-80 steel indicated that, for better weldability, two chemical ranges would be necessary. The two ranges now specified are shown in Table 1, while related data appear in Tables 2 and 3. These modified alloys were successfully quenched and tempered to the 80,000 psi minimum yield with Charpy V notch values of from 30 to 50 ft-lb at −120° F. These are quenched from temperatures determined by mill practices and steel chemistry, and drawn to 1100° F minimum temperature to obtain the above mechanical properties in thickness ranges as necessary to meet the design criteria established by the Navy.

Facilities were not available for the production of shapes. This necessitated the fabrication of the necessary tee bars for structural framing. During 1959, the Materials Processing Division of the Curtiss-Wright Corp., Buffalo, N. Y. produced extruded tee bars of HY-80 material with excellent physical properties as shown in Table 4. These are now being

Table 1—Percent Chemical Composition of HY-80 Steels

Grade	Nominal thickness, lb/sq ft	C (max)	Mn	P (max)	S (max)	Si	Ni	Cr	Mo
HY-80	To 56.1, inclusive[a]	0.22	0.10–0.40	0.035	0.040	0.15–0.35	2.00–2.75	0.90–1.40	0.23–0.35
	Over 51.0	0.23	0.10–0.40	0.035	0.040	0.15–0.35	2.50–3.25	1.35–1.85	0.30–0.60

[a] For thicknesses between 51.0 and 56.1 lb/sq ft, either composition may be supplied.

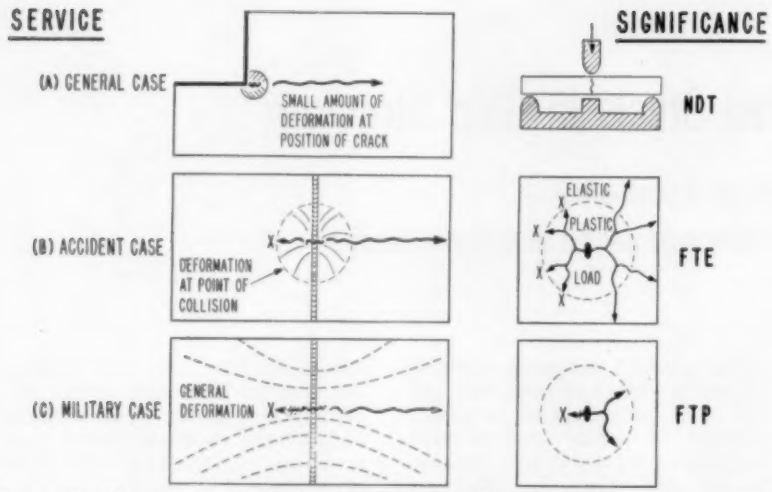

Fig. 1—Significance of crack-starter test results relative to specific service applications.[1] (The "X" mark side represents condition for material above the respective transition temperatures; the other side represents conditions for material below the respective transitions)

Table 2—Mechanical Properties of HY-80 Steel

Thickness, lb/sq ft	Ultimate tensile strength, psi	Yield strength 0.2% offset, psi	Elongation (minimum), % in 2 in. Type 5 specimen	Elongation (minimum), % in 2 in. Type 1 specimen
Less than 20.4	1	80,000–100,000	19	..
20.4 and over	1	80,000–95,000	20	20

Table 3—Impact Requirements[a] Charpy V-notch

Plate thickness, lb/sq ft	Specimen size, mm	Average of 3 tests, ft-lb
10.2 to 20.4 exclusive	10 by 5 (1/2 size)	3
20.4 through 61.2 inclusive	10 by 10	50
Over 61.2	10 by 10	30

[a] Test temperature shall be −120° F + 5° F.
[b] No single impact value shall be more than 5 ft-lb below the minimum average required.
[c] Impact tests are required for information only. Tests are not required for plate less than 10.2 lb/sq ft.

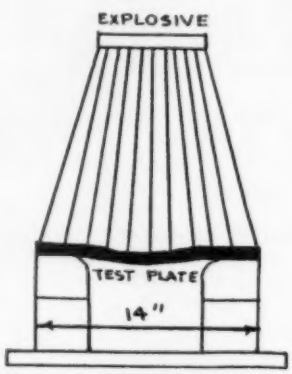

Fig. 2—Schematic of explosion crack-starter test method[1]

Table 4—HY-80 T-bar Preliminary Tests

	Required	Harden 1650 F, temper 1200 F, water quench	Water quench, temper 1200 F, air cool
Tensile strength, psi	...	112,000	112,500
Yield strength, psi, 0.2% offset	80,000 min	94,200	95,700
Elongation	18 min	21.5	21.5
Reduction of area, %	35 min	60	67
Hardness, BHN	...	241	235

Notes: (1) Charpy V at −120° F above requirement of Table 3. (2) Transverse specimens from extruded bar heat treated in laboratory and machined to 0.505-in. tensile bars

used in the construction of a submarine and will probably be widely used in the future for construction of submarines. This also opened the field to the consideration of the production of a complete line of extruded sections for welded construction enabling the designer to obtain finished structures of more uniform design characteristics. For example, it is simpler to produce a bulb bar than an angle. The obvious advantage of this as a stiffener over an angle or flat bar when welded to the plate is self-evident. Steel mills are now scheduling the production of rolled tee shapes of quenched and tempered alloy materials.

The development of this material does not stop with the 80,000 psi yield point but goes on to 100,000 psi yield, 125,000 psi yield and 150,000 psi yield materials. High yield material (100,000 psi) is now being used in the construction of an experimental hull structure. Higher strength material to withstand deeper submergence pressures are extremely desirable when one realizes that presently only a very small percentage of the available water depths in the operation of our submarine fleet is being utilized due to the limitations of material available to the designer.

Paralleling the Navy's work, commercial materials identified as T-1 steels are now produced with similar strength characteristics. These offer considerable new freedom to designers, and within 10 years it is predicted that titanium alloys will be available to remove a large number of the present material limitations due to their notch toughness and strength - weight ratio. As stated previously, notch toughness is one of the criteria and probably the most difficult property to obtain in materials suitable for construction by welding.

By "notch toughness" is meant the ability of materials to perform ductily in the presence of a notch. This ductile performance at low temperatures and in the presence of a notch has very practical meaning when we start thinking of submarines, subtankers and even subcargo ships cruising under the Polar Ice Cap. Figures 1 and 2 give a graphic presentation of the methods for testing for this property of materials. While some correlation has been developed between the explosion bulge test and the Charpy V notch test, the final criteria in the development of materials for miltary use still depends upon the results of its performance in the explosion bulge

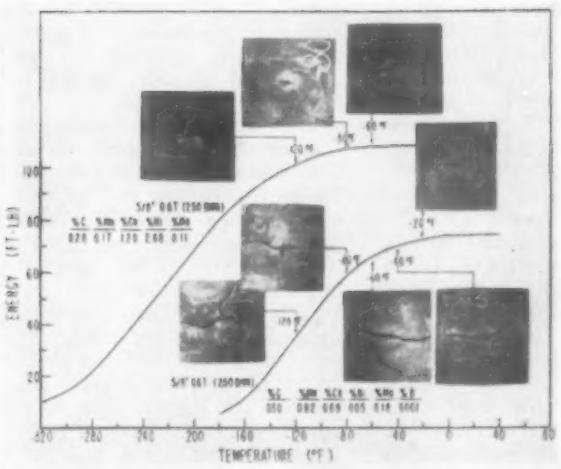

Fig. 3—Relationship of explosion crack-starter tests to Charpy V curves of $^5/_8$-in. "K" (top, steel No. 1) and $^5/_8$-in. "X" steel (bottom, steel No. 8)[1]

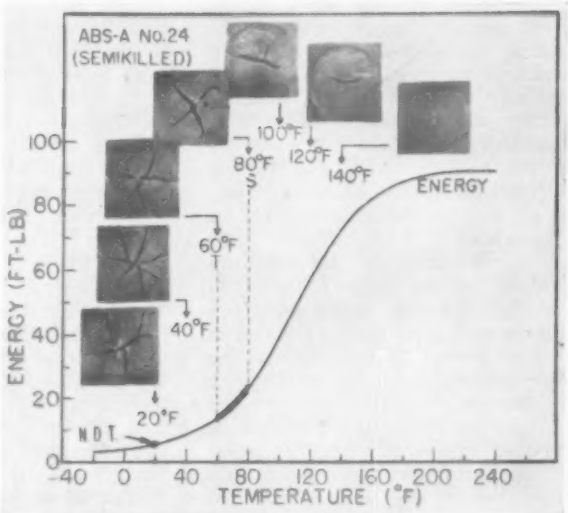

Fig. 4—General relationships of crack-starter test results of ABS-A type semikilled mild steel to Charpy V energy transition curve[1]

test—Fig. 2. The nil ductility transition temperature range is graphically demonstrated for different materials in the graphs from the paper by P. P. Puzak and W. S. Pellini—Figs. 3 and 4.[1] The maintenance of this ductility in the presence of welding presents new and unique problems in the welding of large structures which cannot be postheat treated. It is realized that welding must be performed in such a manner that the material is not severely degraded in the area of the weld heat-affected zone.

Welding Problems

Preheat

The welding of HY-80 materials has presented some very interesting problems in the construction of heavy weldments of high restraint such as submarines.[3, 6, 8] The materials require preheat for successful welding. The preheat must necessarily be limited to 300° F, as indicated by present research, in order to maintain the quench rate of the weld deposit nugget to obtain mechanical properties desired and to prevent degradation of the heat-affected zone. The rate of heat input and the interpass temperature must also be controlled for the reason stated above. The limitation of 300° F interpass temperature and a maximum of 80,000 joules per inch has been established. Table 5 gives the present required preheats, interpass temperatures and heat input limitations as established in the proposed NavShips Instruction 250-637-3, "Fabrication, Welding, and Inspection of HY-80 Submarine Hulls."[2]

Electrode Moisture Control

The heat-affected zone of the weld metal is martensitic in structure with Rockwell C hardness numbers to 42. A great deal has been written about the effects of hydrogen on such structures. To control the hydrogen that might be induced into the weld and heat-affected zone, the welding electrodes must have the moisture content of the coating limited to 0.20% total moisture content. It is obvious from this low figure that we are not talking about free moisture, but moisture of crystallization or combined moisture. No difficulty is experienced by the manufacturer in baking the electrode coatings to this moisture specification. To maintain the moisture at this level during shipment and storage, on the other hand, is another story. The electrodes are packed in hermetically-sealed containers. To date, however, no system has been devised that will give positive assurance that the integrity of these seals is maintained. Spot checking of electrodes from the containers after varying periods of storage and shipment has shown a moisture content of 0.3% or better not uncommon. To control this, the electrodes are all rebaked in a circulating, hot air furnace at 800° (± 25° F) for one hour. They are then transferred while still hot to holding ovens where they are maintained at 250° to 350° F until issued to operators for use. The welding operators are limited to a 4-hr supply of electrodes and are required to turn in any unused electrodes at the end of the 4-hr perfod. These electrodes are placed in a holding oven for a period of not less than 8 hr prior to their reissuance.

Table 5—Preheat and Heat Input Requirements

Preheat for Welding and Tacking: The following table lists the minimum preheat temperatures required for welding HY-80 steel. The temperature shall be based on the thicker joint member.

Plate thickness, in.	Minimum preheat, ° F
Over $1^1/_8$	200
Over $^1/_2$ but not over $1^1/_8$	125
$^1/_2$ or less	75

Maximum preheat and/or interpass temperature shall be 300° F for any plate thickness.

Preheat for Arc-gouging: The minimum preheat temperature for arc-air gouging used for root backgouging or for repair shall be:

Plate thickness, in.	Minimum preheat, ° F
Over $1^1/_8$	150
$1^1/_8$ and under	75

Heat Input: When welding HY-80, the limits for heat input as measured in joules per inch, shall conform to the following table:

Plate thickness, in.	Maximum joules/inch
Less than $1^3/_8$	60,000
$1/^3/_8$ and greater	80,000

For computing the heat input (joules/inch), the following formula applies:

Heat input (joules/inch) =

$$\frac{\text{Voltage} \times \text{amperage} \times 60}{\text{Rate of travel, ipm}}$$

The results of tests at the Ingalls Shipbuilding Corp. indicate the baking procedure outlined above produces electrodes with a total moisture content of the coatings at an average value of 0.06%. These electrodes will gain moisture in the holding oven, due to the hygroscopic nature of the coating, to an average moisture content of approximately 0.1% after a 48-hr period. Checks on the moisture content of electrode coatings in welding operator electrode containers on the job site at the end of a 4-hr period of time shows the time limitation to be satisfactory for relative humidity encountered in this area. The moisture content checked extensively over a period of approximately two years has been below the 0.20% specified for use. The moisture content of electrode coatings is determined by the procedure as outlined in Specification MIL-E-22200.[3]

Weld Cracking

If electrode moisture control and preheat and interpass temperature limitations are not exercised, degradation of the bare metal heated by the welding or an insiduous type cracking is experienced which is difficult to demonstrate by conventional nondestructive testing and is also difficult to correct. This cracking appears to originate in the heat-affected zone and demonstrates itself as either toe cracking, underbead cracking or transverse cracking. This cracking can occur during welding as experienced in the root pass of double welded full penetration joints, or after the weld is completed. The latter may demonstrate itself immediately upon cooling of the weld, or several days later. This is sometimes called cold cracking, or delayed cracking. As T. J. Griffin[4] points out, the low-carbon, martensitic steels (HY-80 and T-1 are low-carbon martensitic steels) are affected by welding as follows: "The heat-affected base metal adjacent to metal arc welds consists, fundamentally, of two zones. The inner zone next to the weld is heated during welding to a temperature, and for a time sufficient, that it is austenized fully or partially. During cooling it transforms into a product, depending on steel composition, that is stronger and harder than the base metal. There is also an outer zone that never attains the transformation temperature but that may have been heated enough to reduce its hardness and strength."

For martensitic steels these conditions and results may not apply literally, and instead of a reduction in strength the effect of welding may exhibit itself as a reduction in toughness or notch ductility, particularly under conditions involving excessive arc heat inputs. Under unfavorable welding conditions the heat-affected base metal may crack during or soon after welding. The cracks can be of several kinds, as follows:

"1. Cracks that originate only in the hard inner zone, after the metal has cooled below its transformation temperature or even several days later. This type of cracking is associated with martensite, regardless of the strength or original microstructure of the steel. For most steels, it is transcrystalline, except in or for the high-strength martensitic steels where the cracks characteristically follow the old austenitic grain boundaries under conditions assumed to be related to alloy migration and enrichment in these regions. Crack formation and extent—i.e., whether the cracks are as relatively short fissures or grow to various degrees of buried or visible gross separations—depends on the percentage of diffusible hydrogen and the degree of strain or stress developed or present during the welding.

"2. Separations resulting from flaws or laminations present in the steel, or from a weakness of the material in certain directions, generally in the direction perpendicular to the plane of rolling. When this type of cracking occurs in the heat-affected zone after the weld has cooled, it may be confused with the true cold crack described above. It is assumed that diffusible hydrogen if present assists in the triggering or growth of such defects and that the degree of strain developed during the welding operation is a major factor in their growth. A condition of flaws or directional weakness in combination with true cold cracking should increase markedly any propensity for gross separations.

"3. Cracking that takes place while the weld is still very hot and usually while the joint is subject to high stresses. The cracking is intercrystalline in character and denotes a weakness between grains or dendrites. Hot cracking can take place without subsequent ingress of air and discoloration and be mistaken for cold cracks. This is unlikely on a statistical basis, since a certain percentage of such cracks will inevitably open to the air at a temperature sufficient to produce discoloration.

"4. In summary, cold cracks start only in martensite and, therefore, occur chiefly in hardenable steels. However, any steel if of sufficient hardenability to form martensite in the heat-affected zone will be or is subject to such cracking."

The technique or procedure of bead application is varied to utilize the tempering bead technique. While the degree and uniformity of tempering may be questioned, practical experience indicates that it is effective. This implies the application of a stringer bead at each toe of the weld, first with the application of other beads over it completing the weld toward the center of the weld nugget—Figs. 5 and 6. The heating from the cover pass is utilized to temper the martensitic heat-affected zone of the previous bead deposited on the quenched and tempered material. Techniques of welding employed to give a gradual change of section also are effective in removing the notch effect that tends to trigger cracks in the hard, martensitic heat-affected zone at the toe of the weld as illustrated in Figs. 5 and 6.

Electrode Coating Development

During World War II considerable experience was gained with the welding of low-carbon alloy steels classified as light armor. Successful welding was performed on these steels without cracking, using austenitic stainless steel welding electrodes. These welds, however, were undesirable due to their low tensile strength compared to the base metal. While they would perform elastically under ballistic attack, they were the weak link for ultimate failure without the utilization of the higher available strength in the base metal. Investigation as to why these electrodes did not produce cracking in the base metal is as follows:

The austenitic weld deposit has a very low or nonexistent yield point which prevented the development of high residual or reactional stresses by yielding sufficiently to strains developed during the welding operation. A later and more important discovery was that the coatings of such electrodes offered only minor amounts of hydrogen in the arc and to this extent paved the way to the coatings of low hydrogen electrodes that are currently in use today.

The tremendous amount of research performed on the effect of hydrogen in welding is beyond the scope of this paper. However, it should be pointed out that the coatings must be free of hydrogen

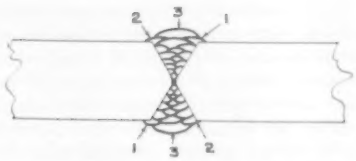

Fig 5—Use of tempering technique for butt welds (Passes 1 and 2 deposited so the heat-affected zone of these passes will be annealed by 3)

forming materials and the moisture content must be less than 0.20% as mentioned previously, otherwise cracking of the hardened heat-affected zone is likely.

This led to the development of a low-alloy, ferritic electrode which carries the Navy designation as Type 260 low hydrogen electrode. This electrode develops strengths comparable to the base metal in the 120,000 psi range. However, it had two drawbacks—one was that the as-deposited weld contained vanadium which produces temper brittleness. Also, characteristics of the electrode made it difficult to use for fillet welding or tee joint preparation.

Further research in electrode development produced what is commonly called "low-hydrogen, iron powder" type coating. This coating gives greater arc stability and better weldability. Most important, however, was the fact that resulting welds exhibited considerable improvement over previous electrodes in that they had a much lower nil-ductility transition temperature. This greater notch toughness now made possible the production of welds in assemblies utilizing the high-yield structural materials with a finished structure of excellent notch toughness. MIL-E-22200, Part I, for this type electrode requires a maximum-minimum limit for the as-deposited weld for tensile strength, a minimum yield point, and minimum notch toughness value, based on the Charpy V notch test, of 20 ft-lb at −60° F.[5] A great deal of research has been performed on submerged arc welding* and other forms of automatic welding such as gas metal-arc welding.

Gas metal-arc welding utilizing 1% oxygen-argon mixture with a controlled dew point to a very low value in connection with the filler wire designated as MIL-B-88 produces satisfactory welds. These welds are smooth on the surface and wash into the base metal smoothly at the edges of the weld producing a great improvement in the contour of welds, especially the tee joint welds. Unfortunately the welding to date is limited to the downhand position. While vertical welding has been performed with satisfactory strength, the change of position for some unknown reason lowers the impact strength or notch toughness of the finished weld. The alloy of filler wire contains vanadium; therefore, welds produced with this filler wire cannot be postheat treated.

Design for Welding

As stated previously, the standard joint preparation for the high tensile materials with slight modifications of procedure are satisfactory for the welding of the high-yield, quenched and tempered materials. Complicated structures such as ships and submarines lead the designer to utilize design configurations that are extremely complicated to weld, especially without producing cracks.

Some of these designs, which produce extremely high reactional stresses and other problems, are outlined as follows:

In submarine construction especially, the use of a cruciform assembly is not uncommon. Figure 7 is an example of its use. It is also commonly used in tank design on internal stiffening members, which are under a high degree of restraint before the application of the concentration of residual and reactional stresses produced by the welding of cruciform configurations usually necessary to weld late in construction. Forged sections with butt welds away from the cruciform are being considered for improvement of weldability where this type of design configuration is desired.

The use of the high-yield-strength materials and the tendency for root cracking gives credence to consideration by the designer to limit the application of fillet welds. The open root of a fillet weld or partial-penetration joint is a common point for crack initiation and propagation in crack-sensitive materials such as the heat-affected zone of the high-yield materials.

Corner joints have always presented a problem to welding. They are a bigger problem with the high-yield materials, as the heat-affected

* Successful submerged arc welding has been performed on 1-in. thick material using a special rod-flux combination developed by the Mare Island Naval Shipyard, Vallejo, Calif. Preparations are being made for its application to submarine construction in these thicknesses while research continues on the development of satisfactory procedures for thicker materials.

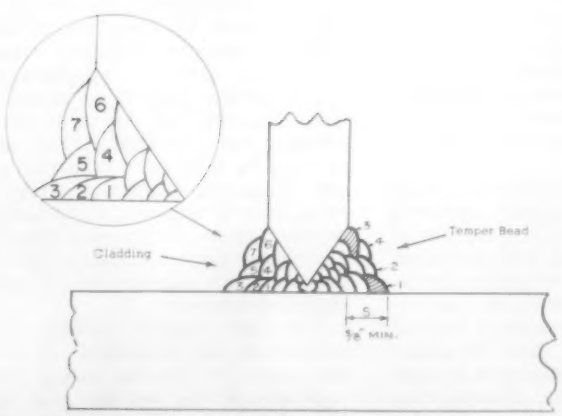

Fig 6.—Use of tempering technique for tee joints. The combination of the temper bead technique and a simulated convex fillet radius is desirable to tee joints. Cladding technique is preferred by some instead of temper bead

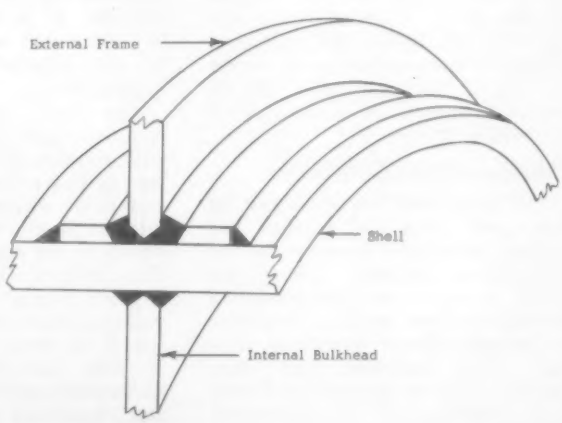

Fig. 7—Cruciform assembly

zone at the toes of the welds are susceptible to crack initiation by reactional stresses which are so high in the corner-joint type of weld under loads. Some progress has been made in forming round corners with butt welds away from the corner. This has greatly improved the designs and eased the construction problems using high yield materials.

In the past, little consideration has had to be given to design of welds over welds. It seems sufficient to point out that the severe reactional stresses from the application of a weld over a finished weld in the high yield material is sufficient to present problems in the initiation of cracks, especially in the hard heat-affected zone of the finished deposited weld.

For structures to be constructed of the high-yield materials, it behooves the designers as well as the fabrication group to consider the requirement for the attachment of fitting lugs and other necessary attachments for moving materials into alignment, which presents dual problems. The first of these is the heat-affected zone that will be left in the base metal from the attachment of the necessary fitting lugs, etc. The second of the problems is an attempt to keep the reactional and residual stresses to a minimum by good fits, limiting the necessity for forcing.

While some postheat treating is possible and present specifications allow stress relief to be conducted at 1025° F (± 25° F) for 1 hr per inch of thickness of the base metal, this cannot be performed on weld metal which has temper brittle characteristics such as welds made with the MIL-B-88 or Type 260 electrode. This low-temperature stress-relief postheat treatment is not too effective in removing residual stresses due to the high strength of these materials at this temperature. Therefore, the designer must consider the necessary allowance for machining in excess of that on materials that can be postheat treated to a lower level of residual stresses.

Fabrication Considerations

The high yield materials can be flame cut using the oxy-fuel gas cutting procedure common to the shipbuilding industry. Flame cut edges, however, produce hardened zones in the base metal quite similar to the heat-affected zone from welding. The hardness may vary slightly from the heat-affected zone from welding. It is impractical to attempt to control this with preheat or postheat treatment during the flame-cutting operation. Flame cutting produces satisfactory edge preparation to receive weld deposits when cleaned of the normal slag attendant to the flame-cutting operation. Flame cut edges which are not to receive a weld deposit, however, produce different problems. Long flame-cut, chamfered edges for the production of gradual changes of section between members of different thicknesses, in many cases, have produced micro cracking. Due to the hardness of the heat-affected zone, they are subject to crack initiation and propagation from the reactional stresses due to loading. Present specifications require postheat treatment at the stress-relief temperatures mentioned above to reduce this hardness and/or the complete removal of the heat-affected zone by machining or grinding. Present specifications require that flame-cut edges in 2 in. and greater thick materials be magnetic-particle tested for cracks.

During the fabrication of HY-80 materials, it is advantageous to use all mechanical fitting clamps possible to eliminate the necessity for tack welding. A large number of relatively new and unique fitting devices have been developed which are outlined in BuShips Notice 9110 dated Dec. 30, 1959.[6]

Backgouging of welds or gouging for repair operations must be considered in light of the degradation of the base metal in certain temperature ranges. This eliminates the consideration of oxyacetylene gouging. Grinding is satisfactory but expensive. Arc-air gouging is satisfactory for use on these materials. The rapidity with which this can be done brings this reasonably well within the heat input limitations imposed on this material for welding. Workmen have been trained to produce quite satisfactorily gouging using this process. It is normally necessary to do a small amount of grinding to get satisfactory surfaces for weld deposit.

The hard heat-affected zones in these materials present problems with relation to the application of low-melting-point alloys to these materials. Stress corrosion cracking has been experienced, for example, in the application of lead-tin alloy solders with their attendant required fluxes.[7] Research to date indicates that careful consideration should be given to the specification of any low-melting-point alloy materials to the high-yield quenched and tempered materials. Pure metals such as lead apparently do not produce this phenomenon while zincs, tins and some of the other metals are capable of producing stress-corrrosion cracking. Overlay materials of nonferrous alloys such as Monel, high-nickel alloy and silver solder are successfully applied to the materials.

The sequence of erection for the fabrication and assembly of quenched and tempered high yield materials requires more attention than is normally experienced with the more common shipbuilding materials.[8] It becomes quite obvious that, if proper care is not exercised during erection, the fitting of intercostals, transverse frame stiffeners and even such simple things as ladder rungs between deep floors out of sequence can present real problems due to the restraint under which the welding must be accomplished.

The welding technique or sequence of weld deposition also becomes increasingly important. Butt welding can be accomplished quite successfully if the block welding technique is employed along with the rigid controls outlined previously. Interruption of welding leaving partially finished welds for an extended period of time presents grave problems. A good sequence should be established and rigidly maintained. Welding supervision should be on an equal level with shipfitting supervision for greater assurance that shipfitting is such that satisfactory welding can be performed.

Quality Control

Need

Fabrication of the quenched and tempered materials, especially in ship construction, falls into the category of relatively new material. The number of variables, which affect the end product and which must be controlled, requires a strong quality control program in order to have real assurance of a reliable end product. Past experience by fabrication of quenched and tempered materials, wherein rigid control was not maintained, is reported as very costly due to discoveries late in construction of defects which caused serious construction delays.

The past practice traditionally established in shipyards of the assurance of quality being the province of the artisan and his immediate supervisor apparently is not satisfactory for the fabrication of high-yield materials. It is an old truism that pride of workmanship differentiates the workman

from the journeyman or, as might be said, the artisan from the helper. This is as it should be since pride of workmanship will produce more quality at less cost than rigid inspection or quality control. The technicalities involved, however, in the fabrication of these materials are such that sad experience has proved it necessary to install quality control over this fabrication and welding to give the answer to such questions as:

1. Is the right welding electrode being used?

2. Is the moisture content of the electrode coatings at the satisfactory level for use?

3. Is the preheat at the satisfactory level and even over the structure?

4. Is the base material quality satisfactory and free from injurious segregations?

5. Do the drawings and specifications incorporate the required control that must be maintained in order to meet the required dimensions?

6. Have those actions or processes that have gone on in the process and fitting of the material before the conscientious welding operator starts his welding helped or prevented him from achieving the quality of welding desired?

If there are negative answers to any of these questions, they will cost many dollars and delays despite the best of welding operators.

Maintaining Effectiveness

To be effective, quality control must start at the beginning of the job planning with the design details and with the materials. It must also exercise control over the accuracy of job instruction and see that in-process inspection is performed as necessary to assure an end product of satisfactory use. This should be done in such a manner that it brings out the better human factors as in any other area when dealing with people, as people are the direct insurers of quality. The quality control program should be so arranged that it points up the good quality of workmanship to encourage the individual responsible for it and at the same time have enough facts to substantiate the quality of the product in its various stages of construction. Such a quality control program is based on a good set of procedures properly checked out, with the necessary inspection, furnishing feedback of information to management. Quality control can actually be thought of in three stages—diagnosis, remedy, and maintenance. By "diagnosis" is meant the necessary information to point up problem areas and furnish information as to their cause. By "remedy" is meant information to develop, as early in construction as possible, remedial procedures to eliminate the cause of the problem. By "maintenance" is meant the holding of the remedies once they are developed. This latter area is the biggest problem in quality control. This requires the cooperation of the entire supervision and inspection personnel concerned with operations. Factual data collected and assimilated under a good quality control system serves as a positive control over maintenance as it will furnish data not only on problems but furnish information on the level of quality establishing confidence in the procedures in use. The author feels the following areas should be under rigidly controlled inspection procedures with feedback of information to a central source, there recorded and tabulated for proof of quality of welded structures of high yield materials:

1. Receipt inspection of plate material.
2. Moisture content of electrode coatings.
3. Preheating.
4. Shipfitting and joint edge preparation.
5. Magnetic particle inspection of all welding with cracks reported as to type, location, and percentage of welding involved.
6. Radiographic inspection of butt welds in prime structural members such as outer shells and pressure tanks, reported as to types of defects and their locations, and percentage of welding involved.
7. Dimensional check of finished welding assemblies and structures, reported against established tolerances.

Conclusion

The quenched and tempered high-yield materials available today for shipbuilding construction are the dreams of the designer a few years ago. These materials present some problems new to the shipbuilding industry. It is proposed, however, that the quality of the end product is far superior to that produced only a few years ago. The strength-characteristic also allows larger welded structures to be built with properties that will withstand the rigors that will be imposed by future miltary activity. New materials on the horizon such as titanium with its promised strength-weight ratio is a challenge to the world to develop satisfactory welding techniques for its application. Higher yield point ferritic materials now being contemplated show promise of good weldability with slight modifications to the technique now employed on the high-yield material of which we have spoken. They will unquestionably require more rigid and careful control during fabrication than the materials in use today.

References

1. Puzak, P. P., and Pellini, W. S., "Evaluation of the Significance of Charpy Tests for Quenched and Tempered Steels," THE WELDING JOURNAL, 35 (6), Research Suppl., 275-s to 290-s (1956).
2. "Fabrication, Welding, Inspection of HY-80 Submarine Hulls," NavShips 250-637-3, in process of development.
3. "Electrodes, Welding, Covered; General Specifications for," MIL-E-22200.
4. Griffin, T. J., "Cold Cracking in the Heat-Affected Zone of HY-80 Welded Joints," *Bur. Ships Jnl.*, 9–17 (May 1959).
5. "Military Specification—Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium and High Tensile Steel, as Welded or Stress-Relieved Weld Application," MIL-E-22200/1 (Ships), Apr. 7, 1960.
6. "Welding of HY-80—Inspection of Welds n Submarine Hull Structure and Control of Fabrication Scars," BuShips Notice 9110, Ser 637-1257, Dec. 30, 1959.
7. "Stress Corrosion Cracking of HY-80 Steel Weldments in Presence of Molten Tin-Lead Solder," Laboratory Report No. C-1819-3, November 1958, by T. L. Sheehan, Materials Laboratory, Portsmouth Naval Shipyard.
8. Gilligan, John A., and England, John R., "The Fabrication and Design of Structures of 'T-1' Steel," Unpublished Report, U. S. Steel Co.
9. "HY-80 Steel Fabrication in Submarine Construction," Bureau of Ships Conference at United States Naval Research Laboratory, July 29–30, 1958.

Influence of Residual Stresses and Metallurgical Changes on Low-Stress Brittle Fracture in Welded Steel Plates

Paper sponsored by IIW surveys failure induced by slowly applied loads in welded and notched wick-plate and pressure vessel tests

BY A. A. WELLS

ABSTRACT. A wealth of information has been accumulated over many years, and in several countries, on the various features of casualty brittle fractures that can be reproduced on the laboratory scale. Where welding, low-carbon steels and notch effects are combined, the testing of large specimens is particularly helpful in giving full opportunity for residual stress effects to operate, and fractures at low levels of applied stress may be produced. The study of many such test results now permits a balanced, although probably still incomplete, judgment on the relative degrees of impairment in strength to be attributed to the existence of residual tensile stresses on the one hand and metallurgical effects concomitant with the generation of residual stresses on the other hand. Discussion within the forum of Commissions IX and X of the IIW, and the conduct of planned experiments arising from them, has contributed significantly to the formation of such a balanced judgment, which may be considered by some as an advance on earlier, more extreme, views.

The present paper represents an attempt to bring together some of the information now available on welded and notched wide plate and pressure vessel tests, where failure is induced by slowly applied loads, so that features are exposed relating to crack initiation and propagation, together with the influence of some types of naturally occurring flaws. The plate thicknesses involved in the survey range from $^1/_2$ to 3 in.

Introduction

The significance of residual stresses with regard to brittle cleavage fracture in welded steel structures has always been elusive. Since these stresses may be present in every structure and yet be difficult to estimate, this is probably not surprising. Certainly their effects have more often been described indirectly than in positive terms; thus, "... provided that the material, including the weld, can behave in a normal ductile manner, then locked up stresses due to welding do not impair the strength of ship structures." (Admiralty Ship Welding Committee, First Interim Report, January 1946.) "The hypothesis that residual stresses lead to failure in fabrication has been of great utility in that modified practices based on the validity of this hypothesis have been proved successful over many years of development in this field of activity." (H. Harris, *Residual Stresses in Metals and Metal Construction*, edited by W. R. Osgood, Reinhold (1954).)

It is thus a safe assumption that both residual stresses and the metallurgical condition of the material should continue to be studied in any complete assessment of the problem. Thus, in the IIW, brittle fracture has been examined both by Commission IX, with the terms of reference since 1954, "The behaviour of metals subjected to welding," and by Commission X, with the terms of reference "Residual Stresses and Stress Relieving." At intervals there have also been colloquia at which the commission memberships have jointly discussed their problems. Much of the work to be described has been discussed before one or the other of the two Commissions and some of the newer work is fruit borne of the discussions.

Although some of the most notable brittle fractures, among them those of the Hasselt bridge and the Schenectady, have occurred under static loadings well established to be below those the structures were designed to bear, it has not been easy to achieve low applied stress fractures in the laboratory. Although fracture stresses tend to diminish with increasing size of specimen, it was established beyond reasonable doubt more than ten years ago, by the extensive tests of sharply notched wide plates in the USA, that the lower limit of average stress is probably the yield point at the notched section at fracture with low-carbon mild steels having suffered no previous loading before tensile test. Reference 1 illustrates this point in review. Nevertheless, it has been recognized that the inhibition of fracture in this way is transitory—involving the so-called initiation—since already running cleavage fractures, as for instance in the Robertson[2] and SOD[3] tests, are not so limited. Fracture propagation may take place more easily, depending to some extent each on the applied tensile stress and the length reached by the crack.

A convincing demonstration of low applied stress fracture was made in the USA in 1949 by Greene,[4] using large square plate specimens, each containing a central butt weld, with paired jewelers' saw cuts as artificial defects in the edges prepared for welding. Cleavage fractures several inches long appeared when the specimens were lightly bent to stretch the surface along the weld. One spontaneous fracture appeared on cooling to −30° C. Others were obtained in a repetition of the experiment by Warren

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and Vaughan.[5] Spontaneous fractures of other types apparently activated by welding stresses and cooling down were obtained in edge restrained plates by Weck,[6] and in notched and welded disks by Hebrant, *et al.*[7] and Vinckier.[8]

The present author repeated Greene's experiment[3] with the help of direct tension application, and in one of several specimens obtained a through fracture at an applied average tensile stress of 21,000 psi. For a short time this result remained a doubtful curiosity, but there have been subsequent confirmations.[10,11] Tests of this type are currently in progress in Japan, Yugoslavia, Canada, the United Kingdom and again in the USA.

A feature of the notched and welded type of wide plate specimen is the local heating associated with the weld. There is strong inference that the heating causes local plastic upsetting along the weld, which is reversed to plastic stretching as the weld cools down. The plastic deformation is also inferred to be intensified at the root of the pre-existing notch. This plasticity could produce two significant changes in the specimen, namely, the placing of the root of the notch in a condition for incipient crack initiation and the creation of an extensive elastic tensile residual stress field around the notch. In this way low stress fracture initiation and propagation in these specimens may at least be qualitatively understood.

Greene's tests[4] on notched, welded and thermally stress-relieved specimens, that invariably failed to give low stress fractures, have been repeated by Kennedy,[12] Kihara, *et al.*,[13,14] and others, and it is also noteworthy that Kennedy's[12] tests on specimens prepared with preheating instead of postwelding stress relief produced no such increase of strength.

These results led Greene, and many others subsequently, to conclude that the removal of residual stresses from a notched and welded specimen increases the brittle strength at least to the value that would obtain if the notch were cut in virgin plate material. This conclusion might be too far reaching if reliance were to be placed on the results solely from as-welded and thermally stress-relieved plates, since the stress relief heat treatment may also ameliorate the effect to prior plastic flow at the notch root, as well as reduce the elastic residual stresses surrounding it.

Table 1—The Strengths of Notched and Welded Plates, Fully and Partially Stress Relieved by Pretension[13,15]

Condition	Specimen No.	Test temperature, ° C	Pretension, 1000 psi	Fracture stress, 1000 psi	Elongation, %	Mode of fracture[a]
Pretension after welding and notching	M 5	−28	7.6	14.2	0.05	S
	10	−28	15.0	24.1	0.07	S
	15	−27	22.0	23.5	0.07	S
	20	−26	29.2	33.9	0.11	H
	5	−54.5	7.2	6.7	0.03	S
	15	−48	21.9	23.1	0.10	S
	10	−49	14.6	21.8	0.06	S
	23	−28	33.6	37.8	0.11	H
	15	0	22.0	36.6	0.19	H
Pretensioned after welding and before notching	M′ 5	−33	7.7	9.1		
	10	−29	14.6	19.3		
	15	−29	22.5	26.8		
	20	−28	30.3	36.2		

[a] S: Single stage fracture at low stress level (no plastic deformation). H: Fracture at high stress level (after plastic deformation).

Nevertheless, it is possible to remove the elastic residual stresses in the broad field surrounding the notch in a welded specimen, by stretching it to the yield point at a temperature somewhat above that at which the loading would cause cleavage failure. There is little evidence to suggest that this type of stress relief would cause significant amelioration of the condition at the root of the notch, as first modified by plastic deformation from welding. It is true that the notch root would be suspected to be in residual compression upon removing the prestretching load, but this state would be rapidly reversed to one of local yield point tension again upon reloading. However, wide plate strength measurements on prestretched plates, reported both by the author[9] and Kihara, *et al.*,[13–15] show significant increases from this treatment. Kihara's [15] later results are the more valuable because they embrace a range of pretension stresses, and notches cut both before and after pretensioning (Table 1). In all cases the applied loads at fracture matched or just exceeded the pretension loads showing that the fracture response depended each time on reaching the same absolute magnitude of stress surrounding the crack. There was no significant effect on applied load at fracture arising solely from the time at which the notch was made.

Similar results to those of prestretched specimens were originally reported by Greene,[4] for specimens mechanically stress relieved by the Linde low-temperature process, and these were successfully checked by Kennedy[12] for correct treatments. Incorrectly treated specimens gave lower strengths. The important change resulting from the mechanical stress relief in all these experiments is the rise in fracture strength; there is almost no corresponding increase in ductility, as there is following thermal stress relief.

These results collectively remain among the most important to demonstrate the role played by the tensile residual stresses alone in notched and welded wide plates, but the arguments have been further clarified by experiments conducted by Soete[16] and reported in the 1960 Houdremont lecture to IIW. This author prepared three specimens of 5.4-in. by 1.34-in. section by 39-in. length, with symmetrically disposed longitudinal slits 22-in. long and 2.9-in. apart. The center of the three ligaments so created in each specimen was then reduced to a thickness of 0.6 in. Transverse fatigue cracks of 0.4-in. length were then developed for small drilled holes in the central ligaments by cyclic loading each specimen, after which the specimens were aged at 250° C for 1 hr. The cracked ligaments were then cut transversely near each end and rewelded so as to create longitudinal tensile reaction stress, the magnitude of which could be gaged accurately by the elastic strain of the outer ligaments of each whole specimen. The specimens were then coded to −20° C and each broken in tension, the average applied tensile stress (whole cross section) to fracture varying only between 10,000 and 19,000 psi. However, the reaction stress in each central ligament before external loading application was already between 62,000 and 66,000 psi. Thus in these experiments the effects of elastic residual stress and prior plastic strain at the notch roots from the initial plastic stretch are not separated, but the nonuni-

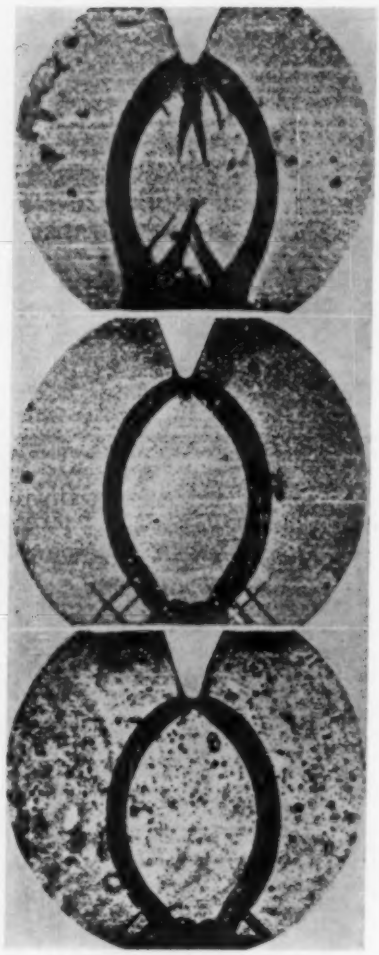


Fig. 1—V-notched specimen of pearlite free steel bent under concentrated load, angle of bend, 1/2 deg, Fry's etch[23]

formly distributed temperature cycling at the notch from the closely adjacent welding in a wide plate has been removed.

Interest has been aroused in the discovery attributed to Mylonas,[17,18] that fracture initiation in a sharply notched specimen may be assisted by plastic precompression. With symmetrical edge notches to a depth of 1.5 in. in specimens of gross width 10 in., this author demonstrates that through brittle fractures may be produced, following precompression, at applied tensile stresses on the net area as low as 40% of the virgin yield, and short arrested fractures from the notch roots at even lower applied stresses. Such fractures are not easily explained in terms of residual stress, although tensile values exist by inference near the notches after the precompression, and Mylonas has offered the explanation that the precompression lowers or exhausts the ductility of the material at the notch roots and so assists crack initiation. Similar lower than yield point fractures have been obtained by Turner[19] on specimens of gross width 3 in. but were not obtained by Spence[20] in precompressed, circumferentially notched specimens of approximately 1/2-in. diam. It is of interesting significance that the lowest through fracture stresses obtained by each of these investigators on comparable types of steel fall approximately in the inverse ratio of the square root of diameter or width, and this will be further discussed. Finally, there is little remaining doubt that extensive plastic precompression can lower the subsequently applied tension ductility and increase the chances of cleavage fracture, even of unnotched specimens of low carbon steel, as shown by Rendall,[21] Drucker, *et al.*[22]

Crack Propagation

Elastic residual stresses resemble externally applied stresses in that they exist in large volumes of material, and may be superimposed tensorially with them provided that yielding does not intervene. Their similarity in effect on fracture to that of externally applied stresses is well shown by Soete's[16] tests already described. Thus it is plausible that they should influence crack propagation as do externally applied stresses.

With reference to elastic stress fields generally, it is apparent that a criterion for crack propagation involving only the magnitude of the tension stress field component normal to the crack, within which field the crack is buried, cannot be sufficient to explain observed behavior. There exists, for instance, the crack or specimen size effect, which reaches its maximum, if geometrical similarity is retained, of strength inversely proportional to the square root of size, when crack initiation is easiest. Thus in sharply notched specimens ostensibly without residual stresses the effect is illustrated by tests of tension specimens containing central arrested brittle cracks of different lengths, by Felbeck and Orowan,[23] and bend tests of sharply notched geometrically similar bars by Wundt.[24] In the former case the initiation was assisted by arranging the crack lengths to be such that the specimens all failed above yield. In the latter, the chosen steel was of alloy type in a massive coarse grained section, heat treated to a particularly brittle condition.

Similar examples may be quoted, where residual stresses apparently play a leading role, and it is maintained that the notched and welded wide plate is one of these. When the propagating brittle crack is still short, it apparently needs to be contained within a tensile field of high magnitude, contributed to by the elastic residual stress system in the as-welded plate, or the comparatively larger exterally applied fracture load in the fully or partially mechanically stress-relieved plate. When the crack is longer, and beyond the influence of the residual stress system, an applied stress, uniformly distributed, and of some lower magnitude between zero and yield is just sufficient to maintain it. Quantitative explanations of this in terms of the size effect have been offered by the author[9] and fully developed by Yoshiki and Kanazawa[24] and Masubuchi.[25]

The existence of the size effect in specimens after precompression, shown by combining the results of Mylonas, Turner and Spence, as above, seems to demonstrate that these fractures too were mainly controlled by the necessity to maintain cleavage crack propagation, and this is supported by the existence in some specimens of Mylonas of the cracks arrested when very short, with those specimens sustaining extremely low applied stresses at this first stage of fracture. If the foregoing evidence is to be accepted, the existence of these short cracks can scarcely be explained other than by the influence of the local tensile residual stresses in addition to the ductility exhaustion from the precompression.

The influence of residual stresses on brittle crack propagation may be demonstrated most effectively when the initiation variable is quite absent, as in the series of tests at the University of Illinois,[27] where a local impact is used to start a crack. In specimens treated to produce alternate fields of residual tension and compression normal to the crack path, on to which applied tension may be superimposed, the running crack is successively observed to accelerate or decelerate as the zones are passed. Velocities between the limits 4000 and 50 fps have been obtained in this way, with rough and smooth textures, respectively, and measured dynamic strains around the crack tip, whose contours of equal value are also larger and smaller, respectively, between the extreme conditions.

Of the available hypotheses the one that still most satisfactorily

seems to embrace all the experimental results is that of Griffith as modified by Orowan[28] and Irwin.[29] In its original form it requires the release from all sources of sufficient elastic strain energy to feed this to the propagating crack at least above a critical rate on a projected cracked surface area basis. With a large plate in tension containing a central initial crack, and with a bar having initial edge cracks, whether in bending or tension, it leads exactly to the relation; propagation resistance $\alpha(1/\sqrt{\text{size}})$ under conditions of geometrical similarity, and this corresponds well with observation under the conditions of greatest brittleness. More recently, the link between the energy balance and the scaling of distributed stresses at the roots of propagating cracks has been demonstrated by Irwin,[30] such that it is possible to infer that the distributions of stress near the root of a crack are similar, whatever the geometry of specimen shape and loading away from the crack. (Measured dynamic strain contours illustrative of the degree to which this is in approximation are given in Reference 27, SSC.118.) The propagation condition then becomes the simple, satisfying one that propagation will continue if the size of the zone around the tip of the crack, enclosing stress greater than given magnitude (say, yield) is greater than a critical value. The principal contending hypothesis involving stress alone is useful technologically because it is easier to apply, but it leaves untouched the important differences due to scale.

The following conclusion may therefore be suggested on the basis of available evidence. Brittle cleavage fracture propagation is influenced by the elastic stress field through which the crack passes, so that externally applied and residual stresses are alike in their effects, which may be estimated according to the tensor summation. In the limit, the character of the crack, that is its direction, speed and visible texture when traveling in a given material at given temperature is controlled by the stress environment at its tip, whether this arises from applied or residual loading, or both.

One of the principal problems remaining in the field of crack propagation is the direct measurement of the environmental conditions at the tip of the crack whereby propagation, crack speed, and arrest are determined, whether these are defined in terms of absorption of energy at the cracked surface, the size of the yielded zone at the crack tip or by indirect means such as the average stress in the member before the crack passed that way. Inferences of crack propagation characteristics of a material involving the strength of a notched bar at the instant of fracture initiation may be suspect, because it is uncertain whether initiation or propagation is the controlling factor: there is a recognized ambiguity in the reasoning that the test is propagation controlled on no other grounds than that the result fits the propagation strength hypothesis without modification. Those tests involving crack arrest[2,3] avoid this difficulty, but because they are usually assessed on the applied stress before fracture, they remain susceptible to changes in the scale at which the test is performed, as the experiments collectively described thus far might indicate. In order to be assessed in terms of the crack tip environment, the strength of the initiating blow and, possibly, the influence of the thermal stress induced by local cooling at the notch would require to be determined, and the double tension test of Yoshiki[25] approaches avoidance of this difficulty. As some observers would agree, there is also a phenomenon akin to momentum in the running crack associated with the deeply curved crack front, especially seen in cracks in thick specimens, which makes uncertain the validity of any measurement involving the position of the arrest point. In short, such crack arrest tests are useful mainly for technological rather than fundamental purposes, at their present state of development.

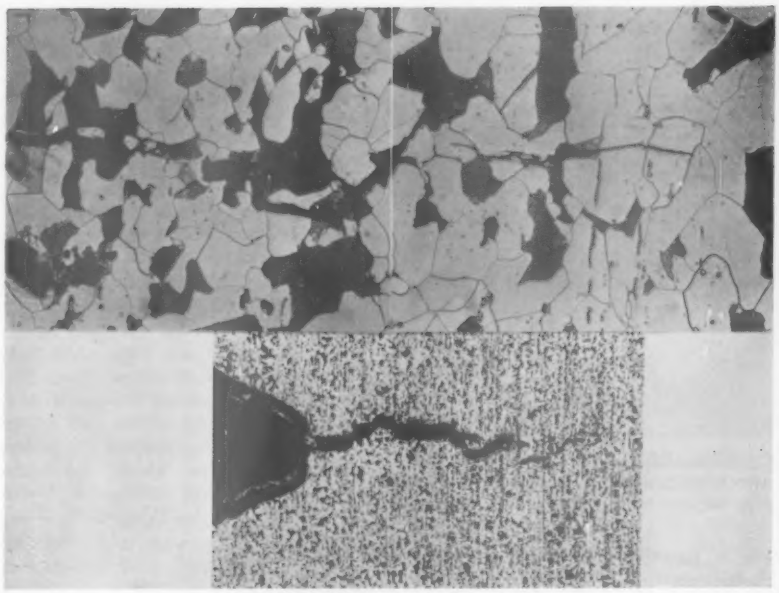


Fig. 2—Macrosection of a partially broken Charpy V-notch specimen of normalized mild steel, angle of bend 5½ deg

Initiation

In devising and analyzing experiments it is desirable to have a working hypothesis, even though it be recognized as crude, and such a hypothesis has been briefly mentioned for the case of crack propagation. The Ludwik hypothesis as modified by Orowan and others, culminating with Hendrickson, Wood and Clark[31] is directly helpful in considering crack initiation. Briefly it is supposed that cleavage cracking will occur if a sufficiently high tensile stress may first be sustained at the same place. Normally, the stress is limited by the occurrence of slip, but slip may be inhibited by reducing temperature, increasing rate of strain, the introduction of triaxiality or at least by "gritting" the slip planes with precipitates as in aging, whereby cleavage resistance is not necessarily silmultaneously increased. The straining rate at the cracking zone is assumed to be increased by several orders when cleavage occurs, so that the latter is self sustained.

Conversely, the high straining rate in crack propagation must be replaced by an alternative stress raising factor in initiation. If the triaxiality is already high, as at a sharp notch, and temperature change is excluded, this must be "gritting" or a similar phenomenon. Several years ago the author suggested

Fig. 3—Machine oxygen cut plate edge with sawn notches placed before and after edge cutting; Fry's etch

strain hardening as an important factor, on the basis of the frequent coincidence between crack initiation and general yield, which is the point on the load extension curve at which strain hardening sets in near the root of the notch. Nevertheless, it appears that homogeneous strain hardening, by major microstructural change, increases the cleavage strength simultaneously with shear strength, so that the relative attributes of strain hardening and strain aging in brittle crack initiation have been questioned. It may therefore be helpful to recognize a further distinction.

The zones of slip and cleavage in a fractured notched specimen do not clearly coincide, as is illustrated by polishing and etching with Fry's reagent on a specimen of high nitrogen steel—Fig. 1. In the Charpy specimen for instance, the slip bands, especially below the surface, are mainly around the periphery of a "hinge pin," tangent to the root of the notch and cleavage traverses the diameter. However, the magnitude of triaxial tension just below the root of the notch and inside the "hinge pin" may still depend upon the resistance to slip along the periphery, as is shown by analogy in the case of a cube with straining bars attached to each of its six faces. Here the tension within the cube may be triaxial, but the magnitude is controlled by the yield of the external straining bars in uniaxial tension. In these two cases the triaxial stress magnitude at a point of cleavage could be influenced both by strain hardening or aging in adjacent regions of low triaxiality, even though there be negligible plastic strain at the point itself. If such reasoning is accepted, then both strain hardening and aging could influence cleavage almost solely to the extent to which they inhibited slip.

Recent work has been addressed to locating the exact position below the root of a notch in a Charpy specimen at which cleavage microcracks first appear, when the specimen is given a light blow so that complete fracture does not occur—Fig. 2. Kasatkin[32] has used specimens of annealed open hearth and air blown converter steels and wrought iron, bent by impact to an angle of only 3–4 deg, through restraint of the hammer in a jig. From detailed observation of the microcracking, twinning and other microstructural changes, he concludes that the most intensely stressed condition which helps the formation and development of internal brittle cracks originates at about 1.5 to 2 mm below the bottom of the notch. Crussard, *et al.*,[33] after examining refitted broken impact specimens, conclude that the lip of the root of the notch in "brittle" specimens almost certainly forms after the initiation of fracture, which is internal, and may be either intergranular or transcrystalline. Work aimed to repeat both these observations, by Davies at the author's laboratory, suggests that the mechanism may sometimes be different. With annealed open-hearth steel his macrosections as in Fig. 2 show the gap at the shear lip to be larger than that elsewhere in partially broken specimens from which, in his specimens at least, the ductile tear must be assumed to have occurred first. This could still be consistent with the first appearances of cleavage even well below the bottom of the ductile tear, but of the many specimens tested and sectioned, in no one could the cleavage be arrested at a sufficiently early stage to observe genuine nucleation.

However, the observations all along these limited fractures confirmed the one important point, that cleavage nucleation, although requiring some plastic deformation at the precise position of nucleation, needs far less (before the individual crystal cleavages join up) than could cause recognizable distortion of the microstructure. This proposition readmits strain hardening as an initiation mechanism.

The following tentative conclusion is therefore stated. Cleavage crack initiation in the region of high triaxiality and low plastic strain at the root of a notch requires a resistance to slip in the adjacent regions of low triaxiality and high plastic strain at least as great as that contributed by high straining rate in subsequent crack propagation. The added resistance may stem from strain hardening, aging or other metallurgical modification of the material in such proportions as these effects jointly operate simply to raise the yield point. Since the plastic strain at the region of high triaxiality is comparatively small up to the point of cleavage crack initiation, change of cleavage strength is probably negligible at the same position in the same time interval.

The distinction now drawn between the separate regions at the root of the notch for critical effects of slip and cleavage helps principally to explain how initiation may be assisted by strain hardening in an already notched specimen, where a similar order of plastic straining before notching may produce little effect, or even a lowering of the fracture appearance transition temperature, when aging effects are minimized. It may be particularly worth consideration in the case of some of Mylonas' experiments, where specimens were notched before precompression, and where aging was minimized by keeping the precompressed specimens under refrigeration before test in tension.

Although it would be difficult to find a case in the literature of brittle fracture experiments where it could be said that strain aging alone was responsible for crack initiation, it may be inferred as of great importance in cases where initiation has arisen with only local yielding. Local yielding within an enclave obeys the condition of compatibility with surrounding elastic strains, whereby the induction of strain hardening is strictly limited. Thus, Kihara's[15] tests with wide plates notched after welding as discussed later, afford one of the few illustrations of crack initiation with local yielding, in his case from elastic residual stress relaxation from the notch cutting. The parent material was a semikilled low-carbon and manganese steel embrittled by high roll finishing temperature. Strain aging properties have not been quoted; it is also not clear whether the specimens were aged after notch cutting and before fracture. There was probably a time interval sufficient for some natural aging.

The study of brittle cracks originating from fatigue cracks is also of some interest. Both Robertson[34] and Soete[35] have shown that fatigue cracks as such are not severe initiators. They will not, for in-

stance, initiate low stress fracture where the crack propagation requirements would otherwise permit this, unless an artificial aging treatment is first applied (Soete[16]). Experiments on notched and welded wide plates load cycled at ambient temperature to produce fatigue cracking extension of the original notches (carried out at the author's laboratory and reported by Lewis[36]), even showed a significant increase of brittle fracture strength compared with specimens loaded straight to fracture at the same low temperature. This may be an example of overaging, where the precipitation "grit" on the slip planes is kept dispersed by load cycling. However, fatigue cracks growing slowly under a warm environment in service, such that appreciable aging can keep up with the fatigue cracking, can lead to spontaneous brittle cracking upon drop of temperature. Such an event was described by Lewis[36] for a welded furnace charging platform subjected to cyclic loading in a steelworks. The brittle cracking appeared when the furnaces were drawn in cold weather.

Welding Thermal Effects On Crack Initiation

It is beyond doubt that the process of fusion welding produces substantial areas of plastic deformation along the weld and adjacent material, as well as the high elastic residual stresses whose existence has often been demonstrated. The amount of strain is calculable from the measured free contraction of the material and the maximum difference of temperature between the weld area and the surrounding material, and the plastic strain field may be exposed in high nitrogen steel by the use of Fry's etch, as in Fig. 3. In this case, an oxygen cut was substituted for a weld in order to avoid the extraneous etching effects resultant upon a difference of potential between weld and parent metal. A fine sawcut introduced before cutting but not completely fused out produces appreciable concentration of slip markings, whereas one introduced after oxygen cutting produces less additional slip. As suggested by Prof. A. H. Cottrell, the testing of impact specimens cut from a weld adjacent zone with their notches already placed in the prepared edge for welding, demonstrates effectively the degree to which the combined heat and plastic deformation from the welding operation prepares the material near the notch root for cleavage crack initiation.

The curves of Fig. 4 prepared by Wheatley in the author's laboratory show comparisons between the parent material (standard milled notches and sawcut notches), the prenotched weld adjacent zone and the material after receiving a standard strain aging treatment before notching. After allowing for the difference between specimens with milled and sawcut notches, the prenotched weld adjacent zone specimens are seen to have fracture appearance transition temperatures raised to values comparable with those of strain aged specimens, but the maximum energy absorptions are lower by a factor of more than 2. It is reasonable to conclude in this case that both strain hardening and strain aging effects have operated to produce such embrittlement.

However, low stress fracture initiation in notched and welded wide plate tests may also be produced from notches of somewhat larger cross-sectional area but cut after welding is complete, as shown by Kihara,[15] one of whose diagrams is reproduced in Fig. 5. A detailed comparison of notches cut before and after welding has been made by Wheatley using a standard notch cut into the prepared edges before welding (I), the same with the weld metal sawed through in addition before testing (III) and a notch of area equal to the aggregate in III, but cut wholly after welding (II). Wheatley used wide plates cut down to 4 in. width for the sake of economy in material and testing facilities, so that the actual fracture stresses (gross area) and extensions to fracture of Table 2 are for mutual comparison of crack initiation behavior alone. His steel was a low-carbon open-hearth grade, *Q* of reference 11. The results confirm

Table 2—The Strengths of 4-in. Wide Specimens Extracted from Wide Plates Notched Before or After Welding; Wheatley (II and III type specimens have the same notch length)

Notch condition	Test temperature, °C	Fracture stress (gross area), 1000 psi	Elongation on 4 in., %
I—	21.0	52.0	2.23
Notched	5.8	42.7	0.04
before	−11.5	54.4	1.45
welding	−15.0	47.7	0.10
	−15.8	44.3	0.05
	−20.6	48.7	0.15
II—	−5.0	46.6	0.14
notched	−8.0	46.5	0.31
after	−16.6	42.4	0.24
welding	−17.6	44.4	0.23
III—As	8.0	53.0	>5
type I	−10.0	15.2	0
butt weld	−15.0	31.2	0.03
metal on notch plane severed after welding	−24.0	12.5	0

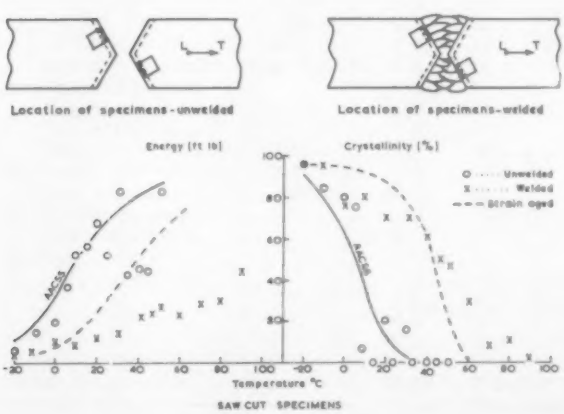
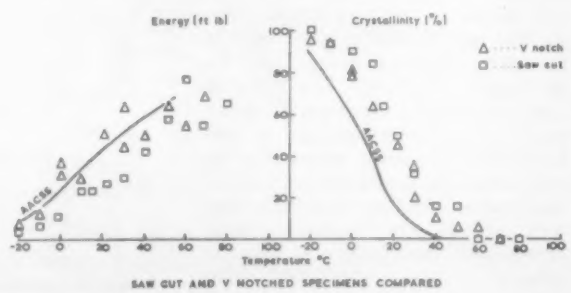


Fig. 4—Charpy energy absorptions and crystallinities for V and sawn notch specimens of parent plate before and after ageing treatment compared with specimens extracted from a prenotched and welded wide plate



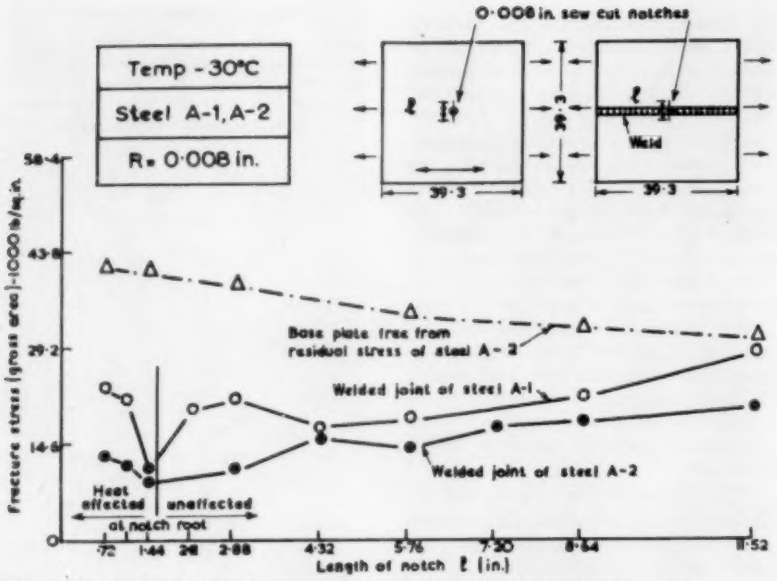


Fig. 5—Effect of lengths of notches cut after welding on fracture strengths (gross area) in welded and notched wide plates[15]

that a notch of given area whose roots were present before welding (III) produces a substantially lower ductility and strength than one of equal area cut after welding (II). Expressed in another way, a notch cut after welding (II) requires about twice the area to produce the same ductility as one cut before welding (I).

Kihara's[15] welded wide plate tests with notches cut after welding, in one case before and in the other after a tensile prestraining operation, partially or fully to remove residual stresses, require further comment at this point. It will be recollected that the comparison revealed no significant change in applied stress at fracture. In one sense this may be understood if it is accepted that the strains in pretensioning are governed throughout by compatibility and the bulk of elastic material comprising the main load-bearing part of the wide plate. Under these conditions the local plastic strains ultimately arising at the root of the notch before final test loading would not vary according to whether the notch was cut before or after pretensioning, so that the condition with respect to crack initiation would also be the same. However, the Steel A used by Kihara appears to have been unusually susceptible to embrittlement because when, in the other case, the initial sawcut notches made after welding were extended well outside the tension residual stress zone, the plates still failed in tension at well under yield point applied stress—Fig. 5. The open-hearth steels used by Wheatley and the author did not behave in this way, by comparison with the many wide plate tests where short brittle cracks were experienced upon first loading, as shown by the necessity to apply yielding loads to the remaining ligaments to reinitiate fracture. The logical deduction from Kihara's tests, that elastic residual stress fields alone could be sufficient to produce enough plastic deformation at the roots of notches to initiate fracture, may therefore illustrate an extreme case, applicable to a very brittle steel.

The small effect of preheating on notched and welded wide plate behavior[12] has also been mentioned. This treatment unless taken to inordinately high and uniformly distributed temperatures scarcely reduces either the plastic weld shrinkage or the elastic residual stresses, so that the lack of benefit from it in a notched and welded test may be understood. In fact, a notched test is not a fair one to assess the benefit from preheating, since the purpose of the latter may be to prevent crack nucleation rather than to limit cleavage fracture from existing weld cracks.

Thus it remains to consider the effects of furnace stress relief at temperatures 650° C and lower, and some notched and welded wide plate strengths and extensional strains to fracture are given in Table 3 for low-carbon open-hearth steels P, Q and S, described in Reference 11. (See also Reference 13.) It is seen that strength and ductility are almost unimpaired down to stress relief temperatures of 500° C, below which there is rapid deterioration. At 500° C the degree of elastic stress relief is of the order 50%, so that if crack propagation and elastic residual stresses were the only consideration, fracture would be expected at any applied stress greater than 50% of yield. But the strength is still consistently at yield point, so that

Table 3—The Strengths of Furnace Stress Relieved, Notched and Welded Wide Plates

Steel	Stress relieving temperature, ° C	Testing temperature, ° C	Initial flaw area, sq in.	Extension, %	Stress, tons/sq in.	Comments
Pb 1	650	−8	..	..	15.0	Kennedy's tests. No fractures without supplementary impact
2	650	−8	..	..	18.4	
3	650	−8	..	..	15.7	
4	650	−25	0.44	1.49	15.0	...
5	650	−56	0.42	0.69	16.6	...
6	650	−69	0.44	0.48	19.2	...
7	650	−64	0.50	0.31	17.9	...
8	500	−56	0.30*	0.24	18.4	* Fracture near end; possibly from weld crack occurring at lower load
9	500	−54½	0.40	0.78	17.9	...
10	450	−55	0.45	0	17.3	...
11	650	−80	0.44	0.75	18.5	...
12	650	−69	0.41	0.56 (0.32)†	17.9	† Measured over shorter gage length wholly within low temperature area
Qb 1	650	−25	0.50	2.2	21.2	...
2	650	−49	0.43	0.55	21.2	...
3	650	−70	0.54	0.93	21.9	...
Sb 1	650	−62	0.40	1.04	24.9	...
2	650	−86	0.40	0.62	27.4	...

the major influence in this case is clearly crack initiation, and it is plausible that temperatures above 500° C are sufficient to remove much of the prior hardening and aging effects at the notch root. In order to observe the degree to which the properties of notched and welded specimens could be restored Wheatley compared the fracture elongation of his types II and III notched and welded specimens after stress relief at 650° C, with those of identically notched unwelded specimens without the stress relief. Five of the former specimens gave elongations between 1.32 and 1.75% while the latter reached 4.0% elongation It must be concluded that the stress relief does not produce a complete restoration.

However, the results of Table 3 with specimens treated at 650° C and pulled at temperatures down to −86° C are of interest, in showing the large temperature interval below the fracture appearance transition temperature (25° C for Steel P, −5° C for Q and −27° C for S; 75% crystallinity, Charpy V notch) at which thermal stress relief is still at least uniformly effective.

In summarizing, an order of severity with regard to the amount of additional plastic deformation required to reach crack initiation can be suggested, for artificial notches of given length and sharpness, each placed in an elastic stress field of the same magnitude and extent in a welded wide plate. It is convenient to list them in order of diminishing severity, thus:

A—Notched before welding (with or without preheat or mechanical stress relief)—spontaneous fracture on cooling.

B—Notched after welding, with or without or before or after mechanical stress relief—fracture after quasi-elastic loading.
Notched before welding, followed by furnace stress relief between 450 and 500° C

C—Notched before welding, followed by furnace stress relief between 500 and 650° C—brittle fracture after ductile extension.
Notched without welding.

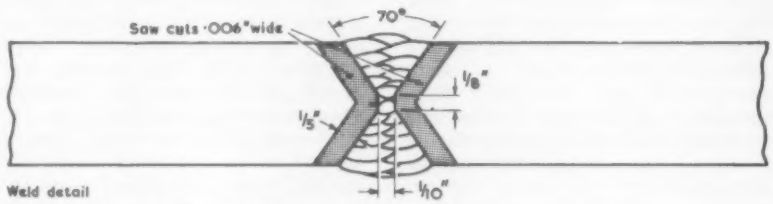
The order is justified, because the literature affords controlled comparisons between each pair of conditions. The grouping may be more arbitrary but it attempts to stylize the major differences as seen in testing with the sizes and sharpness of notch within the limits that have been examined. Unfortunately, there is insufficient evidence to assess fatigue cracks as initiators, even if their sharpness could be defined, but their tendency is toward the B classification, such that they become more severe A flaws as the material around them is allowed to age. All B type flaws are, in any case, likely to tend toward A as their size increases at given sharpness.

The precompression experiments on notched unwelded specimens are difficult to compare on the above basis, because of differing geometries, but the notch severity produced by the treatment appears to be similar to that induced by notching before welding.

Thick Plates

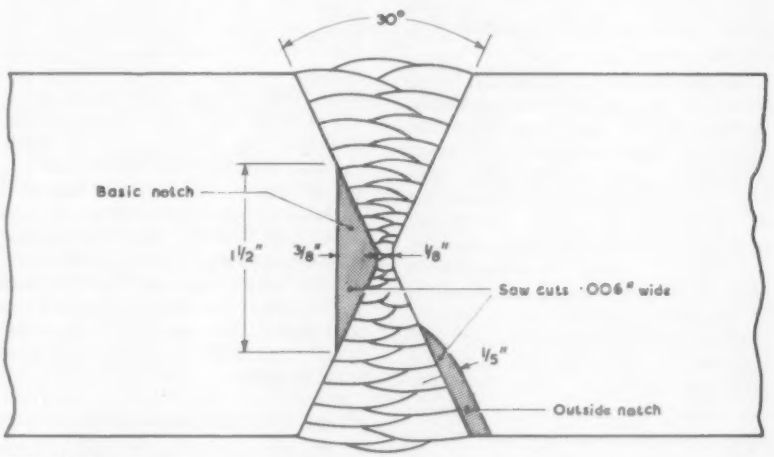
The foregoing discussion has been restricted mainly to work conducted on low-carbon steel plates of a variety of compositions and manufactures, and up to about 1 in. thick. Among the welded and notched wide plates tested in the United Kingdom and Japan there are examples of rimmed and semi-killed as rolled, and fully killed, normalized steels. Apart from differences of transition temperature, and most of the tests have been conducted below such temperatures, some of the steels have been demonstrated by conventional tests to age more than others, and this is reflected in the case with which the artificial defects initiated brittle fractures in the wide plates.[11] Both manual and automatic welding methods have been included among those examined. Additional interesting features have emerged, however, from tests carried out in the United Kingdom on 3-in. thick manually welded plates.[37]

The steel for these tests was of silicon killed low carbon type, in the normalized condition, and Charpy specimens extracted from plates of the same cast rolled to 1 and 3 in. thicknesses gave closely similar transition properties, both for energy absorption and crystallinity (longitudinal and transverse; 15 ft-lb, −15 to −22° C, 75% crystalinity, 10 to −11° C). Manual welds were made with a double-vee preparation in both cases, and the results below are confined



Weld detail
2 runs No. 8 s.w.g. electrode 170 amp
Subsequent runs No. 6 s.w.g. electrode 220 amp

1 in. thick plate specimens



Weld detail
2 runs No. 8 s.w.g. electrode 170 amp
Subsequent runs No. 6 s.w.g. electrode 230 amp

3 in. thick plate specimens

Fig. 6—Artificial notches in thick and thin manually-welded plates

for clarity to those made with rutile covered electrodes. It was experienced at an early stage that the manner of notching before welding in the thicker plate exerted considerable influence on the results, as demonstrated by the contrast in behavior between the so-called center and outside notched plates. The roots of the notches in both thicknesses lay in similar positions with respect to the heat-affected zones, and the aggregate notch areas did not differ appreciably between the positions or thicknesses—Fig. 6. However for tests between −10 and −45° C, only one out of three specimens gave a low stress fracture in the thinner plate, to be compared with four out of six center-notched specimens and four out of four outside notched specimens in the thicker plate. The position with regard to the outside and center notches was reversed after thermal stress relief at 650° C, when all specimens gave yield point or greater strengths, since the thinner plate specimen reached a fracture extension of 1.5%, the three center-notched specimens an average of 0.16% and an outside notched specimen 2.5%, at temperatures averaging −30° C. The low ductility values for the center notched specimen in the stress relieved condition may be associated with high triaxiality at a completely buried notch. The corresponding high value for the outside notched specimen can certainly be associated with division of the aggregate area of the notch into four widely separated parts, each of rather small dimensions. The difference on this basis serves to heighten the contrast in behavior between the center and outside notch cases in the as-welded condition.

A plausible explanation can be offered in the residual stress distribution, which was approximately measured by a longitudinal slitting technique after it had been seen from the paths of fractures that the latter tended to avoid the center of plate in tests in the as-welded condition. The measurements showed that the uniaxial equivalent longitudinal residual stress component at the center of plate had been reduced to zero by the multirun welding technique. The longitudinal (and, by inference, the transverse) components reached tensile yield point at the weld surfaces, so that the transverse component would approach yield point compressive at the weld center. Thus the brittle cracks in the as-welded condition were initiating from the center notch at its ends into the highly stressed areas toward the plate surfaces before running transversely in the plate, whereas the outside notches were already within a biaxial yield point residual stress field. This evidence suggests that the behavior before heat treatment of an electroslag type of weld might be rather different under comparable testing conditions, since here the residual stresses tend to be tensile within and compressive outside.[38]

Notwithstanding the informative results obtained in these tests with transversely notched welds longitudinal to the direction of tension, further interesting data involving low-stress fractures were casually obtained from the transversely-loaded welds joining the ends of the specimens to the loading equipment. In several cases due to inadequate control, areas of slag entrapment and lack of fusion were obtained between weld and parent metals. These caused premature low applied transverse stress fractures from end to end along the fusion boundary, mainly just inside parent metal. When they occurred at very-low applied stresses the fractures were incomplete, penetrating from end to end only to one-third plate thickness. With initiation at applied stresses over 20,000 psi, however, the fractures were complete, turning at nearly 45 deg to the direction of applied tension along the weld and plate midthickness. The weakening influence of the surface residual stress transverse to the weld can scarcely be doubted in the light of these results. Moreover, in as-welded construction the fractures point to a significance that may be attached both to crack travel along the fusion boundary and slag entrapment defects at this plane. Those defects that propagated were about 1 x 0.25 in. In one case a similar fracture was initiated by a semicircular longitudinal hot crack between runs of weld metal at the weld surface, the diameter of which was only 0.5 in. It may be stated in deference that some of these end welds were produced by welders in training, to whom the defects and low-stress fractures were salutary illustrations of the value of weld quality!

Fractures Longitudinal to Welds

The experience mentioned, of low-stress fractures running alongside welds in thick plate lends further significance to wide plate tests first conducted on cross-welded plates by Kihara, *et al.*[39] and subsequently repeated in the author's laboratory. In these tests an artificial flaw and longitudinal weld were made in the customary manner on specimens that had first been butt welded transversely at their centers. Thus the brittle crack could be initiated at high or low stress with the assistance of the longitudinal residual stress system, so as to propagate into any desired section of the transverse weld metal, grain coarsened heat-affected zone or brittle zone. SOD tests were also made with transversely welded plates, so that the crack could be projected into the same zones. An interesting phenomenon appeared in both these tests, of the propagating crack turning away from the transverse weld to run parallel to it and up to 8 in. away, irrespective of the exact plane of origin. This happened for low but not for high applied-stress fractures.

United Kingdom tests have confirmed the result, and it has been concluded that the crack deviation is a residual stress effect, dependent upon the principal tension (residual + applied) stress trajectories. This would explain the absence of the effect at high applied-stress level, before which residual stress relief would have taken place. In only one case in Kihara's tests did the crack follow the fusion line at low applied stress, and this was in a quenched and tempered steel, as a result of which it was concluded that fracture along welds was a serious risk only in cases where weld metal or adjacent zones were appreciably more brittle than parent metal. This question was followed by Cotterell at the author's laboratory by tests on as-welded plates of 1/2 and 1-in. thick fully killed grain-controlled normalized steels.

Temperatures in the range −50 to −60° C were chosen, corresponding with those for 50% crystallinity in the steels concerned, together with basic low-hydrogen mild steel and nickel bearing welds metals, of corresponding transition temperatures −10° C, and lower than −50° C, respectively. Cross-welded test plates were used with slowly-applied tension, and notches were incorporated at various positions from 0.08 in. inside the transverse weld metal to 0.4 in. outside the fusion plane. Apart from two low stress fractures, diverted into the parent material (apparently by residual stresses as concluded above), and apparently associated at initiation with hot cracking at the sawcut plane in the nickel-bearing weld metal, the remaining fractures were at high applied stress. Except in one case

with mild steel weld metal, there was also substantial plastic extension before fracture. No critically prone crack initiation position could be detected in the tests, on a comparative basis, but there was a tendency for a propagating crack to follow the fusion boundary when mild steel electrodes were used, even if it did not start quite in this zone. In no case did a crack run unimpeded within the bulk of weld metal, the woody nature of the fracture surface in such cases being associated with many arrests, restarts and seeming attempts for the crack to reach the fusion boundary again. This work suggests that the penalties are not obvious for using weld metal with a transition temperature somewhat higher than the plate, although such conditions would not arise from deliberate choice.

Although these investigations cast some light on the significance of zones of differing brittleness on the boundaries of welds, the subject has been deemed of sufficient importance for the convening of a working group of Commission IX (Chairman G. M. Boyd) with the terms of reference to explore the metallurgical concomitants of residual stress.[40]

Conclusions

On the basis of the work reviewed, primarily based on the notched and welded type of wide plate test together with the exploration of a variety of low-carbon mild steels, associated weld metals and thermal or mechanical treatments, the following conclusions have been reached:

1. Brittle cleavage fracture in notched specimens including those large enough to be representative of structural assemblies, whether welded or unwelded, requires the fulfillment of the conditions both for initiation and propagation. Each is necessary and in combination they are sufficient. Insofar as the criteria are separable, propagation is involved with absolute levels and distributions of elastic *stress* and initiation with plastic *strain*, although not exclusively so.

2. Cleavage fracture propagation is influenced by the elastic stress field through which the crack passes, so that externally applied and residual stresses are alike in their effects, which may be estimated according to the tensor summation. In the limit the character of the crack, that is its direction, speed and visible texture when traveling in a given material at given temperature, is controlled by the stress environment at its tip, whether this arises from applied or residual loading, or both.

3. Cleavage fracture initiation in the region of high triaxiality and low plastic strain at the root of a notch requires a resistance to slip in the adjacent regions of low triaxiality and high plastic strain at least as great as that contributed by high straining rate in subsequent crack propagation. The added resistance may stem from strain hardening, aging or other metallurgical modification of the material in such proportions as these effects jointly operate simply to raise the yield point. Since the plastic strain at the region of high is comparatively small up to the point of cleavage crack initiation, change of cleavage strength is probably negligible at the same position in the same time interval.

4. Plane artificial defects in welded wide plates of low-carbon (mild) steel may be compared in their effects on fracture initiation on the basis of their existence within and transverse to a field of yield point elastic tensile stress, whether applied or residual. They become more severe as they increase in length (or area), and sharpness to the limit of the natural crack. When compared at given length and sharpness they may be placed in the following order of diminishing severity, with regard to the additional local or over-all plastic strain needed for initiation.

Notched before welding, with or without preheat or mechanical stress relief.

Notched after welding, with or without or before or after mechanical stress relief.

Notched before welding, followed by furnace stress relief between 450 and 500° C.

Notched before welding, followed by stress relief between 500 and 650° C.

Notched without welding.

5. Limited evidence on the behavior of plane natural defects in cleavage crack initiation, principally from casual observation in wide plate tests, suggest that their severities at given length in a given elastic stress field are qualitatively similar to those of plane artificial defects. Thus they are more severe the higher the temperature at which they are formed during or after the welding operation, and those formed near ambient temperature may be made more severe if aging is induced.

6. The influence on cleavage crack initiation and propagation of both natural and artificial plane defects in welds in thick plate is strongly dependent upon their location with respect to the nonuniformly distributed residual stresses and plastic strains.

Acknowledgments

Although data from many sources have been used to compile this survey, much has also remained unused. The author particularly appreciates the speed and willingness with which much new material from many sources has been placed before Commissions IX and X to facilitate this type of work; this, in itself, creates a problem of digestion and he would plead frailty rather than hostility with regard to unused material. Much of the work described, too, has been made possible by sponsors, too numerous to mention individually, but their contributions are nonetheless appreciated. Thanks are also due to those of the author's colleagues who have given details of their work that will be fully reported in due course.

It cannot be too strongly emphasized that the opinions expressed are personal, and do not in any way represent collective views of the IIW or its Commissions IX and X. However, the transactions of the Commissions have been greatly influential in permitting the formation of such personal opinions by the author and others, and this privilege of participation and access is warmly acknowledged.

References

1. Wells, A. A., *Welding Research*, **7**, No. 2, 34 (April 1953).
2. Robertson, T. S., *Jnl. Iron Steel Inst.*, **175**, 361 (December 1953).
3. Feely, F. J., Northup, M. S., Kleppe, S. R., and Gensamer, M., THE WELDING JOURNAL, **20** (12), Research Suppl., 596-s (1955).
4. Greene, T. W., *Ibid.*, **14** (5), Research Suppl., 193-s (1949).
5. Warren, W. G., and Vaughan, H. G., *Trans. Inst. Welding*, **16**, No. 5, 127 (October 1953).
6. Weck, R., *Welding Research*, **6**, No. 4, 70 (August 1952).
7. Hebrant, F., Louis, H., Soete, W., and Vinckier, A., *Rev. Soudure*, **13**, No. 1, 3, IIW-IX-181-56 (1957).
8. Vinckier, A., THE WELDING JOURNAL, **24** (9), Research Suppl., 354-s (1959).
9. Wells, A. A., *Trans. Inst. Naval Arch.*, **98**, 296 (1956).
10. Kihara, H., and Masubuchi, K., Rept. No. 30, Transportation Technical Research Inst., Tokyo, April 1958. Also: *Welding Research Suppl.*, **24** (4), 159 (1959).
11. Wells, A. A., BWRA Report B.6/1/58, to be published in the *British Welding Journal*, 1961. IIW-X-274-61. See also: Admiralty Advisory Committee on Structural Steel Report P2, HMSO, 1960.
12. Kennedy, R., *Crit. Welding Jnl.*, **4** (11), 529 (1957).
13. Kihara, H., Masubuchi, K., Iida, K., and Oba, H., IIW Document X-218-59, Japan Welding Engineering Society.
14. Kihara, H., Masubuchi, K., and Ishii, H., IIW Document X-220-59. Ishii Iron Works Co., Ltd. Also: *Welding Research Suppl.*, **24** (11), 451 (1959).
15. Kihara, H., IIW Document X-258-60, April 1960.
16. Soete, W., *Rev. Soudure*, **16**, No. 2 165 (June 1960).

17. Mylonas, C., Drucker, D. C., and Brunton, J. D., THE WELDING JOURNAL, **23** (10), Research Suppl., 473-s (1958).
18. Mylonas, C., *Ibid.*, **24** (10), Research Suppl., 414-s (1959).
19. Turner, C. E., Admiralty Advisory Committee on Structural Steel, Report RP163. To be published.
20. Spence, J., Thesis, Department of Applied Mechanics, University of Sheffield, 1959.
21. Rendall, J. H., Cambridge Conference on Brittle Fracture, Septembes 1959. To be published HMSO.
22. Drucker, D. C., Mylonas, C., and Lianis, G., THE WELDING JOURNAL, **25** (3), Research Suppl., 117-s (1960).
23. Felbeck, D. K., and Orowan, E., *Ibid.*, **30** (11), Research Suppl., 570-s (1955).
24. Wundt, B. M., ASME Paper 59-MET-9, Metals Engineering Conference, Albany, N. Y., April/May, 1959.
25. Yoshiki, M., and Kanazawa, T., *Jnl. Soc. Naval Arch. Japan*, No. 102, 39 (1957).
26. Masubuchi, K., Report No. 29, Transportation Technical Research Inst., Tokyo, April 1958.
27. Barton, F. W., and Hall, W. J., Ship Structure Committee Report 130, Washington, National Academy of Sciences, National Research Council. See also: SSC 131, 118, 117, 112 and 111, and *Welding Research Suppl.*, **24** (4), 169 (1959).
28. Orowan, E., *Repts. on Progress in Physics*, **12**, 214 (1948–49).
29. Irwin, G. R., *Trans. Am. Soc. Metals*, **40A**, 147 (1948).
30. Irwin, G. R., *Jnl. Appl. Mech.*, **24**, No. 3, 361 (September 1957).
31. Hendrickson, J. A., Wood, W. A., and Clark, D. S., *Trans. Am. Soc. Metals*, **48**, 540 (1956).
32. Kasatkin, B. S., *Fizika metallov i metallovedyenye*, **8**, No. 1, 75 (1959).
33. Crussard, C., Borione, R., Plateau, J., Morillon, Y., and Maratray, F., *Jnl. Iron & Steel Inst.*, **183**, 146 (June 1956).
34. Robertson, T. S., *Engineering*, **172**, 444 (Oct. 5, 1951).
35. Soete, W., IIW Public Session papers, Opatija, Yugoslavia, 1959.
36. Lewis, E. M., Cambridge Conference on Brittle Fracture, September 1959. To be published HMSO.
37. Wells, A. A., BWRA Rept. B.7/4/60. To be published in the *British Welding Jnl.*, IIW-X-276-61 (1961).
38. Soete, W., *Rev. Soudure*, **15**, No. 4, 3 (1959).
39. Kihara, H., Yoshida, T., and Oba, H., IIW Document X-217-59, Kawasaki Dockyard Co. Ltd.
40. Boyd, G. M., IIW Document IX-260-60

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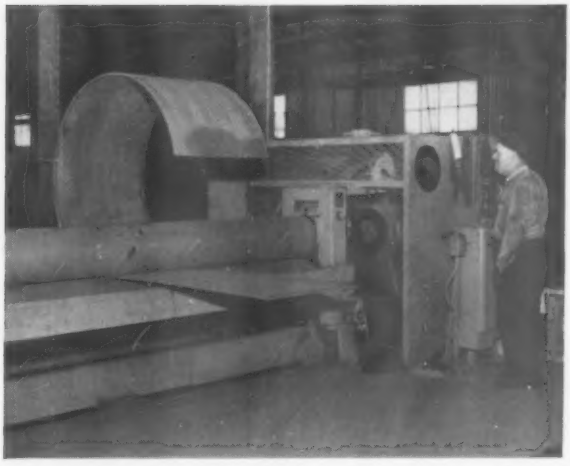

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